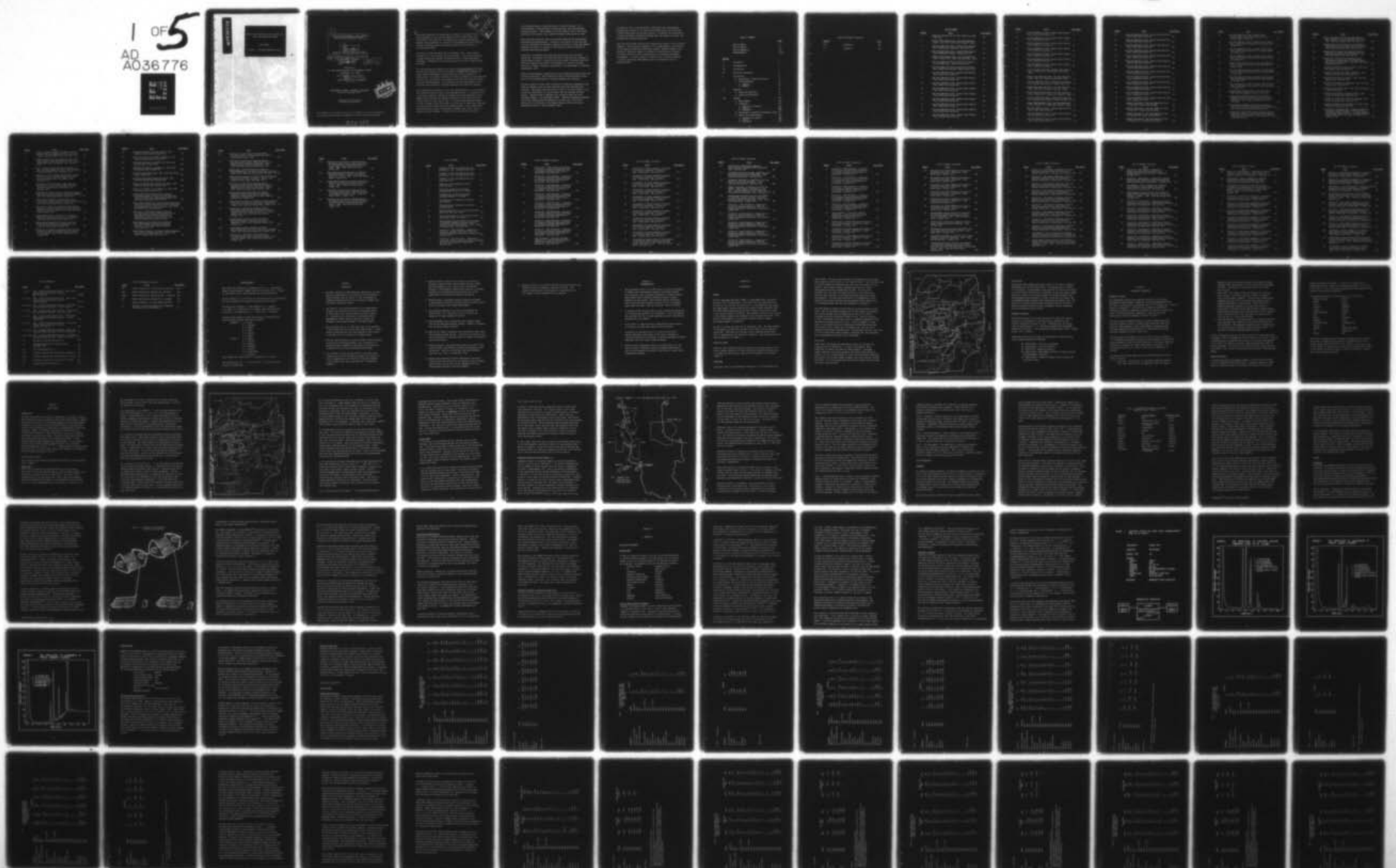
AD-A036 776 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITI--ETC(U)
NOV 76 S L SANOCKI, P B SIMON, R L WEITZEL DAMD17-75-C-5046

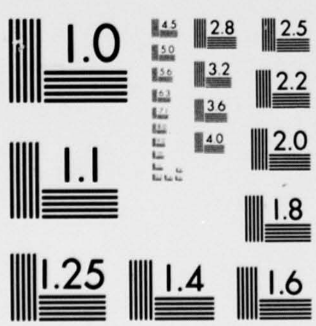
UNCLASSIFIED NL

1 OF 5
AD
A036776



OF 5

36776



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITION PLANTS

FINAL REPORT

VOLUME I - IOWA ARMY AMMUNITION PLANT

6

AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITION PLANTS.

9

FINAL REPORT.

VOLUME I, IOWA ARMY AMMUNITION PLANT.

10 S.L./Sanocki, P.B./Simon, R.L./Weitzel
D.E. /Jerger, J.E./Schenk

11 November 1976 12 418p.

Supported by

U.S. Army Medical Research and Development Command

Washington, D.C. 20314

Gareth Pearson, Project Officer

15

Contract No DAMD 17-75-C-5046 new

ENVIRONMENTAL CONTROL TECHNOLOGY CORPORATION
Ann Arbor, Michigan 48104

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

391 613

LB

SUMMARY

This report describes the methodology and results of an aquatic field survey conducted at the Iowa Army Ammunition Plant (IAAP) during 1975. The purpose of this study was to establish the biological and chemical impacts of the discharges of a munitions load/assembly/pack (LAP) facility. The most significant munitions component handled at this facility is trinitrotoluene (TNT).

The IAAP is located ten miles west of Burlington, Iowa. Three streams originate on, or pass through, the plant property. Brush Creek originates on plant property and receives the greatest input of treated wastewater discharges. Consequently, this stream received the primary interest during the study.

Two field surveys were conducted, one during the spring period (19-27 June), and the other during the fall (6-16 October). Samples were obtained from eight stations established in Brush Creek, plus from two stations in Spring Creek in an attempt to discern any impact attributable to the explosives disposal area. In addition, seven industrial outfalls were monitored during the field sampling program. The stream stations were established so as to facilitate the correlation of stream conditions with industrial outfalls.

Water samples were obtained at each of the stream stations on five consecutive days during each survey, using a grab sampling technique. In addition, each of the seven industrial outfalls was sampled five times during each survey. Samples were collected daily during the operation of the facilities, but without regard for exact time of day. A 48 hour diurnal sampling program was also included in the first survey to verify that no significant variations in water quality occurred during the sampling program. These samples were characterized with respect to nutrients, minerals, heavy metals, and six munitions related compounds. The munitons related compounds included

2,4,6-trinitrotoluene, 2,6-dinitrotoluene, 2,4-dinitrotoluene, 1,3,5-trinitrobenzene, 4-hydroxylamino-2,6-dinitrotoluene, and 2-hydroxylamino-4,6-dinitrotoluene. Three sediment cores were taken at each of the stream stations on both surveys, with a similar analysis scheme applied to them.

River biota was studied in terms of periphyton diatom and non-diatom algae and benthic macroinvertebrates. The goal of this portion of the study was to relate differences in biological community structures to water and sediment chemistry data and/or to location in and along the stream in relation to munitions containing discharges.

Collections of periphyton were taken from both natural and artificial substrates. The material collected from natural substrates was utilized for species identification of diatom and non-diatom algae. Periphyton taken from artificial substrates was used for determination of species occurrence, ash-free dry weight, chlorophyll concentration, and measurements of adenosine triphosphate (ATP).

Benthic macroinvertebrate communities were also sampled using both natural and artificial substrates. The collections of benthic macroinvertebrates were used only for the determination of species abundence and occurrence.

The water quality of Brush Creek is affected by industrial discharges as was shown by increased levels of major dissolved solids and biostimulating nutrients. The average dissolved solids burden in the lower reaches of the stream were approximately 30 percent higher than the upstream reference station. Concentrations of phosphorus and nitrate-nitrogen were also noticeably higher in the downstream reaches. Industrial monitoring indicated that boiler blowdown water discharging at the north end of the Group 1 facility and the discharge of the sewage treatment plant were the most significant sources of these increased levels.

Low levels of 2,4,6- trinitrotoluene (α-TNT) and/or its transformation products were observed in the aqueous and sediment phases at all stations of Brush Creek except the reference station. In general, the concentration of munitions-related compounds was highest near the industrial sources, and decreased with distance downstream.

Minor variation between stations were observed with respect to the biological community. These variations appeared to be of short duration, with recovery of the community observed at downstream stations. Observed trends in the biological communities appeared to correspond to simultaneous variations in nutrient levels and α-TNT concentrations in the aqueous and sediment environments. It was not possible to discern which of these two factors, or possibly some other undetermined factor, was responsible for the observed effects.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF APPENDICES

LIST OF APPENDICES (continued)

ACKNOWLEDGMENTS

The support and assistance of personnel from the U. S. Army Medical Research and Development Command, specifically Captain John P. Glennon, Dr. Mark Warner, and J. Gareth Pearson was greatly appreciated.

We are grateful to Mr. Jack Polson, Mr. Ron Barron and Mr. Thomas Martin for their assistance and cooperation during the field surveys.

This report was prepared by a team composed of S. L. Sanocki, P. B. Simon, R. L. Weitzel and J. E. Schenk, with typing and final production of the manuscript by S. Y. Conant and R. J. Ptaszek.

Personnel participating on field survey teams and responsible for sample analysis and data compilation included:

Chemistry -	P. B. Simon
	R. C. Eisenman
	G. J. Wagner
	M. M. Davis
	M. L. Bateman
	J. L. Barney
Biology -	D. E. Jerger
	S. L. Sanocki
	R. L. Weitzel
	D. F. Kriewall
	D. L. Penrose
	R. F. Gendernalik
	P. A. Pryfogle

Data analysis was assisted by D. A. Scherger and G. W. Brumo.

The consultation of Dr. J. C. Posner and Dr. P. G. Meier is also gratefully acknowledged.

SECTION I

CONCLUSIONS

1. The major influence of IAAP industrial operations on the water quality of Brush Creek can be attributed to the discharge of boiler blowdown water at station I1, and the discharge of phosphorus-containing wastes from the sewage treatment plant and several industrial outfalls.

2. Low levels of 2,4,6-trinitrotoluene and its transformation products were observed in the aqueous and sediment phases of Brush Creek at all stations except the control station B1. In general, the concentration of munitions-related compounds was highest near the industrial sources, and decreased as the stream descended to the IAAP boundary.

3. High concentrations of 2,4,6-TNT were found in the sediments of Brush Creek station B4 during both survey periods. A major source of these materials was found upstream of this station, at the site of an old "pink water" treatment lagoon.

4. When the carbon adsorption treatment systems on IAAP processing facilities are functioning properly, the concentration of munitions-related compounds in the waters of Brush Creek can be expected to be in the low parts-per-billion range.

5. The occurrance of high concentrations of 2,4,6-TNT in non-flooded soils from the old lagoon treatment area adjacent to Group 1 suggests that the half-life of polynitro aromatics is much longer under these conditions than in sedimentary deposits.

6. Species diversity trends for both natural and artificial substrates indicated minor shifts between stations, however any effect appears to be of only a short term duration. Recovery of the periphyton community was observed at different locations in the stream during both surveys, but it was always seen at station B8 in relation to station B1.

7. Observed shifts in periphyton species diversity correspond to simultaneous variations in nutrient levels and TNT concentrations in the aqueous and sediment environments.

8. The periphyton community occurring on the sediments was affected more (i.e., diversity) in the fall than in the spring due to higher sediment TNT levels.

9. Species dominance and occurrence was very different during both surveys indicating seasonal changes. However, differences were not great between substrates.

10. Ash-free dry weight, chlorophyll a and autotrophic index trends were different between surveys. A heterotrophic population was more characteristic of May-June, while in October the population was more autotrophic.

11. Possible affects on the heterotrophic species, in terms of ash-free dry weight, were observed in Brush Creek during the fall survey only. There is an indication that some inhibitory factor(s) (i.e., TNT) is causing this trend.

12. Benthic macroinvertebrate species associations and species diversity were most effected by the industrial waste effluents when in direct contact with the soft sediments and least effected when associated with hard sediments.

13. Species diversity of the benthic macroinvertebrates indicated some inhibitory factor was present at stations B7 and B8. This cannot be explained due to the absence of toxicological data with respect to these compounds on such organisms.

SECTION II

RECOMMENDATIONS

1. The environmental fate of 2,4,6-TNT should be further investigated to identify the transformation pathways and determine whether toxic materials, such as aromatic polyamines, are being produced under aerobic and/or anaerobic conditions present in water, sediment and soil systems. These studies would be coordinated with current photolysis research and focus on the old treatment lagoon area near Group I and the "red water" pond at Group 800.

2. A concerted effort should be made to develop analytical methodology for monitoring RDX and HMX in the environment. After such methods are available, the fate of these compounds and their transformation products should be assessed.

3. Study effects on algae production, biostimulation and inhibition of production by algal assay against field conditions.

4. Delineation of limiting factors (i.e. water quality and/or habitat limitation) with respect to the fish be attempted by live box procedures in the vicinity of specific wastewater effluents. Apparently fish avoid areas of waste discharge.

5. Perform a more concentrated study in a localized area (i.e. the worst effluent) of species in mud/silt sediments where TNT has built up, and determine the extent of the effect on benthic macro-invertebrate diversity.

SECTION III

INTRODUCTION

GENERAL

The Iowa Army Ammunition Plant (IAAP) is a government-owned, contractor-operated, Class II installation. Until early 1975 the installation was divided into two sections, one under the U. S. Army Ammunition Procurement and Supply Agency, and the other under the Atomic Energy Commission (AEC). The Atomic Energy Commission vacated their portion of the facility prior to the current project's initiation. The principal activity at this facility is the loading, assembly, and packaging of high explosive munitions. This function is performed by the principal contractor, Mason & Hanger - Silas Mason Company, Incorporated.

The IAAP is located ten miles west of Burlington, Iowa. The plant consists of approximately 20,000 acres, of which about 7,000 acres are leased for agriculture, 7,500 acres are forested, and the remaining acreage being used for administrative and industrial operations. The plant facilities are shown schematically in Figure 1.

RECEIVING WATERS

There are three receiving streams of interest on the IAAP property, two of which originate outside of the plant and receive pollutional inputs prior to entering the IAAP property, and one which originates on the property (Figure 1).

Long Creek

Long Creek, which is the westernmost watercourse, can be subdivided into

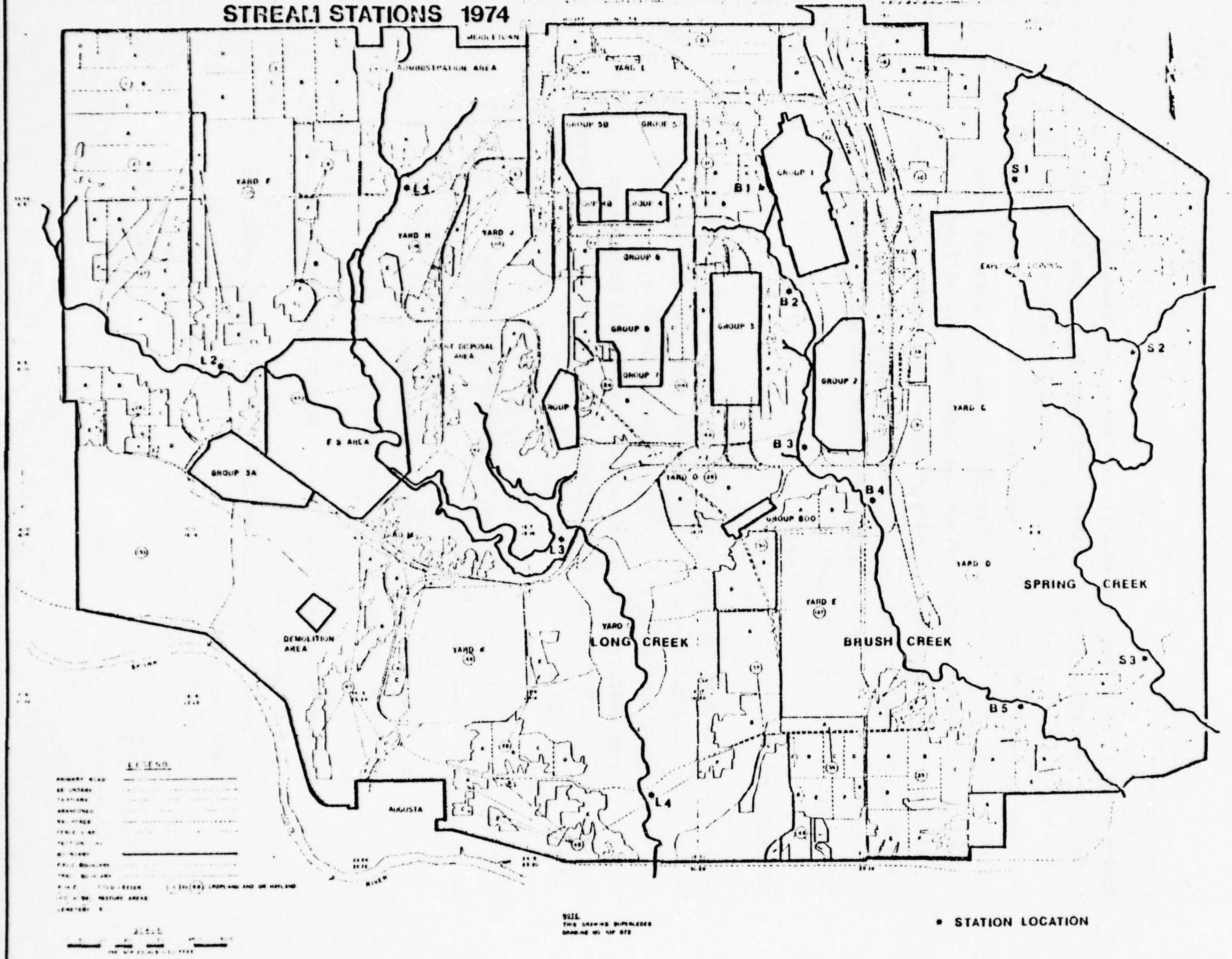
four sections. The upper reach consists of the main branch of the Creek which enters the plant property on it's western boundry. Flow from this reach is derived primarily from agricultural runoff and the effluent from the Danville, Iowa secondary sewage treatment plant which is located approximately two miles upstream from the IAAP. The only direct discharge into this reach from IAAP activities is the effluent from Group 3A, which consists of x-ray film processing wastes and treated TNT wastewater. The additional opportunity for contamination of this stretch of the Creek by mililary unique compounds exists, however, due to its passage through the test area designated FS in Figure 1.

This main branch is joined in the FS area by the second portion of Long Creek. This second branch originates on the IAAP property and receives only surface drainage from the administrative area, and no direct discharge from plant activities is known to occur. The third section of this creek system is Long Lake, which is a man-made impoundment lying immediately downstream from the FS area. The final segment, or lower reach, of Long Creek receives the discharge from Long Lake during high flow periods, surface runoff from the adjacent land, and sand filter backwash from the water treatment plant. The discharge from this lower reach is into the Skunk River which ultimately discharges into the Mississippi River, approximately ten miles south of Burlington.

Brush Creek

Brush Creek flows through the east-central portion of the plant and ultimately into the Skunk River. It drains a watershed of about 6,300 acres, of which 5,300 acres are plant property. The stream itself originates on the plant property, and except during periods of rainfall, its flow consists mainly of treated industrial waste discharges and effluent from the main sewage treatment plant which services the IAAP facilities. It is this stream which received the primary interest during the project reported herein.

FIGURE 1. SCHEMATIC OF IOWA ARMY AMMUNITION PLANT, BURLINGTON, IOWA STREAM STATIONS 1974



Spring Creek

Spring Creek flows through the eastern portion of the plant, ultimately discharging into the Mississippi River. The upstream portion consists of two branches: the westernmost branch consists of surface runoff alone as it enters plant property and is susceptible to military unique contamination as a result of its passing through the explosive disposal area; the easternmost branch consists of surface runoff and the effluent from the secondary sewage treatment plant serving West Burlington, Iowa. The stretch of the Creek on IAAP property downstream from the junction of these two branches receives no direct discharges, and any incremental flow is derived from surface runoff.

PERSONNEL CONTACTED

The initiation date of the subject contract was 1 March 1975, and was basically a continuation of a previous contract performed at this facility during the later half of 1974[1]. Coordination of the project with the funding agency - U. S. Army Medical Research and Development Command (U.S.A.M.R.D.C.) - was accomplished through Captain John P. Glennon and Dr. Mark C. Warner.

Individuals contacted at the IAAP, and who assisted in expediting the survey program included the following:

- Mr. Thomas Padley - Director of Operations
- Mr. George Mathis - Chief of Production
- Mr. Jack Polson - Laboratory Director
- Mr. Ronald Barron - Head Chemist, Director of quality control and environmental laboratory
- Mr. Thomas Martin - chemist in charge of data gathering and and report filing

SECTION IV

HISTORICAL INFORMATION

COMPRENSIVE SURVEYS

Two comprehensive surveys were performed previously by the US Army Environmental Hygiene Agency (USAEHA) at the Iowa Army Ammunition Plant. The first of these surveys was performed during 13-17 September 1971, with the purpose of evaluating "...facilities and operations concerned with industrial and domestic wastewater treatment and disposal, potable water supply, solid waste disposal, swimming pool operation, and water monitoring and pollution abatement activities at IAAP".[2]

This first survey determined potential pollution problems associated with TNT treatment by means of leaching ponds (which have since been abandoned), and chromate, nitrate, and phosphate contamination from container washing and rinsing operations. These potential problems have been addressed since this first survey.

The second survey, performed on 10-19 July 1972, had as its objective "...to determine and quantify the impact of plant domestic and industrial waste discharges on local receiving streams and to establish a biological baseline as a reference for future water quality evaluations". The conclusions arrived at as a result of this study are summarized as follows:[3]

The effects of Iowa Army Ammunition Plant waste discharges can be outlined as follows:

a. Long Creek. Long Creek is in a moderately degraded condition as it flows into the Iowa Army Ammunition Plant, the cause of

degradation most likely being effluent from the Danville Sewage Treatment Plant and nutrients in surface runoff from surrounding farm land. Long Creek is of high water quality as it flows from the plant.

b. Brush Creek. The industrial waste discharges, which form the major portion of the Brush Creek flow, are able to support a fairly diverse aquatic community. Effluent from the Main Sewage Treatment Plant and the fly ash storage area together exert a slight adverse effect on water quality. Brush Creek is in a moderately degraded condition as it flows from the plant.

c. Spring Creek. Effluent from the West Burlington Sewage Treatment Plant maintains the upper area of Spring Creek in a poor condition. Runoff from the Division B Burn Area does not adversely affect water quality as it flows from the plant.

d. Long Lake Reservoir. Long Lake Reservoir was thermally stratified with consequent oxygen depletion at the lake bottom during the sampling period. The moderately degraded water of the main branch of Long Creek does not adversely affect lake water quality, as indicated by favorable macroinvertebrate indices.

A third comprehensive survey of the IAAP facilities was undertaken during the summer of 1974 by Environmental Control Technology Corporation.[1] This was a screening survey to establish the potential for the site being amenable to the study of the affect of munitions compounds (specifically TNT) on aquatic organisms. The results of this survey indicated a high potential for success of such a study, and thus generated the project being discussed herein.

MONITORING PROGRAM

A routine water quality monitoring program at the IAAP has been carried out by the contractor since October 1969. In general, samples are taken weekly at stations located at the influent and effluent of the various

streams traversing the property. A total of six stations were so established from the inception of the monitoring program up to the end of June 1972. At that time several sampling points were changed and two additional stations were established.

The parameters monitored in this program include the following:

Ammonia nitrogen	Arsenic
Barium	B.O.D.
C.O.D.	Cadmium
Chloride	Chromate
Copper	Cyanide
Dissolved Oxygen	Flouride
Iron	Lead
Phenol	Phosphate
Selenium	Silver
Dissolved Solids	Suspended Solids
Sulfate	Zinc
Mercury	Total Heavy Metals
pH	Temperature
Nitrate	Oil

The results obtained from these analyses are summarized twice annually, and provide a comprehensive data base for the water quality of the streams as they enter and leave the plant property. Unfortunately, due to the location of these stations, more critical reaches of the streams in the interior of the plant property, nearer the wastewater outfalls, have no such continuous data base.

SECTION V

FIELD SURVEY

INTRODUCTION

Two field collections were carried out during 1975, one during the spring period (19-27 June) and one during the fall period (6-16 October). Samples were collected to allow for the chemical analysis of water and sediments, evaluation of the species diversity and distribution of periphyton and benthic macroinvertebrates, and potential for biodegradation of munitions compounds. Samples of periphyton from selected stations were also collected for the analysis of ATP, which was then related to periphyton chlorophyll and ash-free dry weight. Station locations used during this survey were established based on the following conditions: a) the present sampling program conducted by plant personnel, b) the effluent locations from various operation groups and lines, and c) the data received through past reports [1, 2, 3, 4]. Sampling stations were relocated before the onset of the 1975 water quality survey based on the results of the 1974 survey (see Figures 1 and 2)[1].

Stream Station Location

The following station scheme was observed during these two recent surveys; refer to Figure 2:

<u>Brush Creek</u> -

Station B1 is located about 155 meters above the 1974 B1 station. This station is the most upstream, above a boiler blowdown effluent, thus serving as a reference station for Brush Creek. The stream flows intermittently in this particular area. When it does flow, primarily during the spring and early summer, it is approximately one meter wide and two to fifteen centimeters deep at this station. Substrate type is

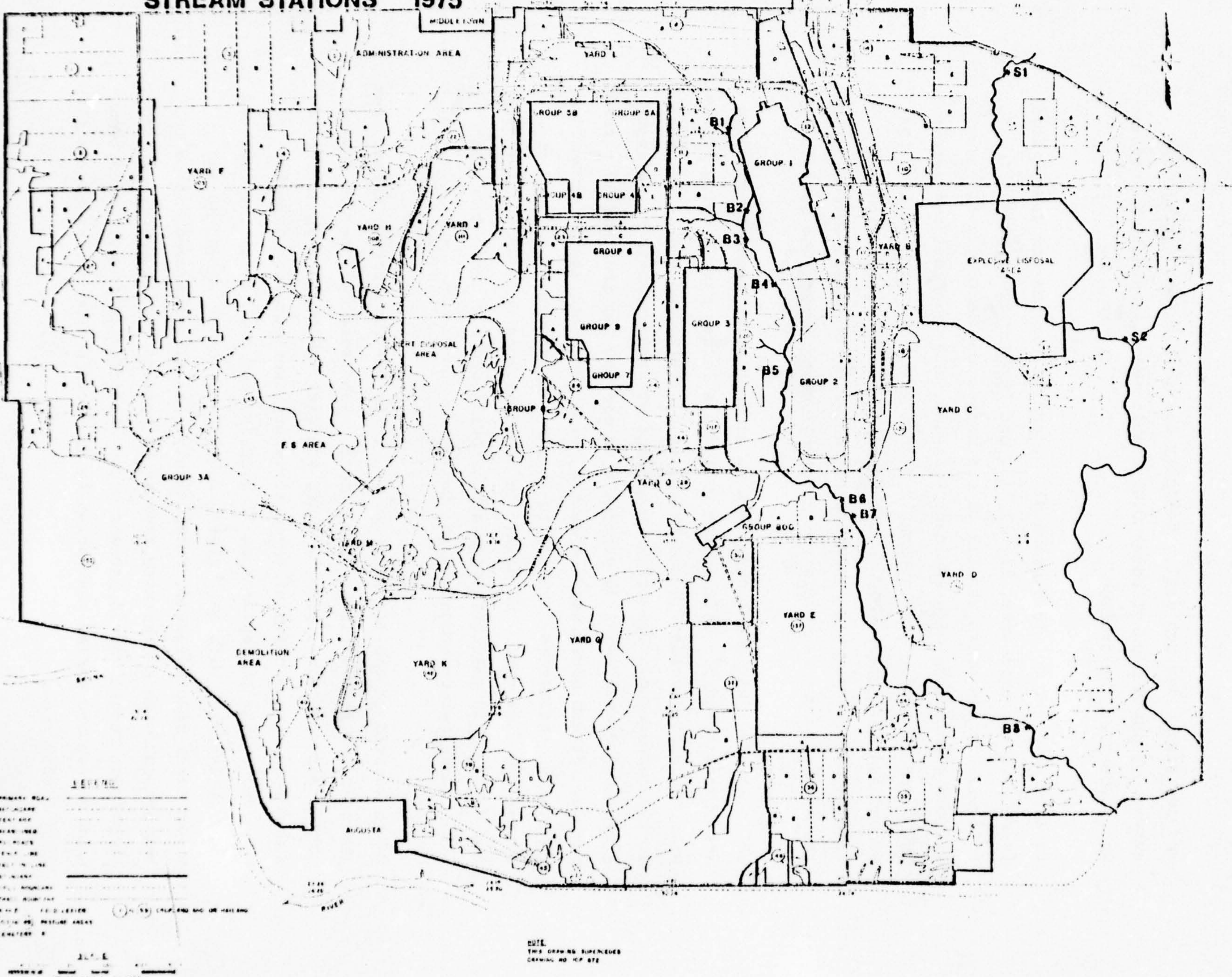
mud and washed out top soil. Velocity was 13.1 cm/sec during the survey, giving a flow of about 0.014 cubic meters/second. No riffle was present at the station.

B2 is equivalent to old station B1 [1], and is located downstream from four industrial effluents, I1, I2, I3, and I4 (see descriptions to follow). Stream width was 1.5 to 1.8 meters and depth was five to fifteen centimeters with sediments of sand, mud, charcoal and detritus. There was no riffle area present. Velocity was measured at 13.1 cms/second and 16.2 cms/second for the spring and fall collections, respectively. Flow was approximately 0.030 cubic meters/second during the spring survey and 0.024 cubic meters/second during the fall survey.

B3 is located just downstream from an industrial effluent originating from Lines 4 and 5. This stream included a large, fast flowing riffle with velocity recorded in the spring at 61 cms/second and in the fall at 104 cms/second. The riffle consisted of approximately 60 percent gravel and coarse sand, 30 percent fine mud and detritus and 10 percent rubble. Stream width was 2.4 meters, with the depth ranging from five to twenty centimeters. Substrate in the main channel consisted of coarse and fine sand. Velocity and flow readings were 20.4 cms/second and 0.059 cubic meters/second in the spring and 7.6 cms/second and 0.031 cubic meters/second in the fall.

B4 is located at the old B2 site [1]. It is 90-100 meters upstream from the most upstream effluent from Line 2. Substrate type in the channel varied between coarse gravel, sand, and clay. Width was about 1.8 to 2.1 meters with a depth of seven to twenty centimeters. Velocity measured during the spring was 11.3 cms/second and during the fall was 16.2 cms/second, with discharges of 0.031 cubic meters/second and 0.048 cubic meters/second, respectively. A well developed riffle was present with a substrate type of 80 percent coarse gravel and sand, 10 percent rubble and 10 percent muck. Velocity readings ranged from 26.5 cms/second during the spring to 33.5 cms/second during the fall in this riffle area.

FIGURE 2. SCHEMATIC OF IOWA ARMY AMMUNITION PLANT, BURLINGTON, IOWA STREAM STATIONS 1975



B5 is located downstream from two Line 3 effluents, I5 and I6, and a Line 2 effluent, I7. Stream channel width was 1.8 and 2.4 meters and two to ten centimeters deep, with sediments of coarse gravel and sand. Measured velocities for spring and fall were 21.3 cms/second and 6.28 cms/second, respectively, while the calculated flow was 0.027 cubic meters/second and 0.088 cubic meters/second, respectively. There was no riffle present during the fall collection, however during the spring sampling period a riffle area was present where the velocity was determined to be 34.4 cms/second. A substrate type of 80 percent charcoal and 20 percent coarse gravel and sand was found at this riffle.

B6 is located about 90 meters upstream from the IAAP wastewater treatment plant. The riffle area immediately upstream gave velocity readings of 33.5 cms/second during the spring and 26.5 cms/second during the fall. Substrate type was 70 percent rubble and 30 percent coarse gravel and sand, with a hard clay base. This station includes a small pool with a width of 1.5 to 2.1 meters. Depth was about five to fifteen centimeters. Coarse gravel, sand and charcoal were the substrate types. Stream velocity measured in the pool channel was 15.2 cms/second yielding a flow of 0.042 cubic meters/second in the spring. Values of 28.3 cms/second and 0.047 cubic meters/second were the velocity and flow measurements during the fall collection period.

B7 is located about 23 meters downstream from the IAAP wastewater treatment plant and parallels the old station B4 [1]. Width was 4 to 4.5 meters and depth was five to twenty three centimeters. Substrate type consisted of coarse gravel, sand, charcoal, and mud. Velocity and flow readings were 15.2 cms/second and 0.082 cubic meters/second during the fall periods. No well-defined riffle was present during the fall collection due to high water levels. The riffle in spring exhibited a velocity of 26.5 cms/second. About 80 percent coarse sand, pebbles, and charcoal, and 20 percent fine sand made up the substrate type.

B8 is located at the old B5 station [1], over sixteen hundred meters

downstream from the B7 station. This station serves the function of measuring recovery should detrimental effects be observed in the upstream areas. The large pool at this station, width of 4 to 4.5 meters, and depth of thirteen to twenty five centimeters, had a tendency to collect large mats of Cladophora, five to ten centimeters thick, during the spring. Coarse sand, mud and detritus was the substrate type. Velocity readings during the spring and fall surveys were 15.2 cms/second and 24.4 cms/second, respectively, yielding discharges of 0.153 cubic meters/second and 0.183 cubic meters/second, respectively. The riffle was located about 9 meters upstream from the pool. Velocity measurements were 45.7 cms/second during both spring and fall. Substrate type was 60 percent rubble and 40 percent gravel, rocks, and coarse sand.

Spring Creek -
S1 is located on the westernmost branch, upstream from all known effluents, and about 385 meters upstream from the explosive disposal area. This area receives mostly surface runoff and is the Spring Creek reference station. Width was 1.5 to 2 meters and depth was five to twenty three centimeters. Substrate type was mostly silt and sand. Velocity ranged from 20.4 cms/second in the spring to no flow during the fall. The flow in June was 0.32 cubic meters/second. The riffle area was small during the spring collection with substrate type of pebbles and stones.

S2 is located downstream from the explosive disposal area and upstream from the confluence with the east branch. This station included a large and deep pool having a width of four to five meters and depth of ten to forty three centimeters. Velocity readings were 9.1 cms/second and 30.5 cms/second for spring and fall, respectively, with flows of 0.149 cubic meters/second and 0.037 cubic meters/second. The riffle area was further upstream from the pool area and had a velocity of 3.4 cms/second during the spring. There was no riffle area during the fall collection. The substrate at this station had a

fine to heavy cover of silt.

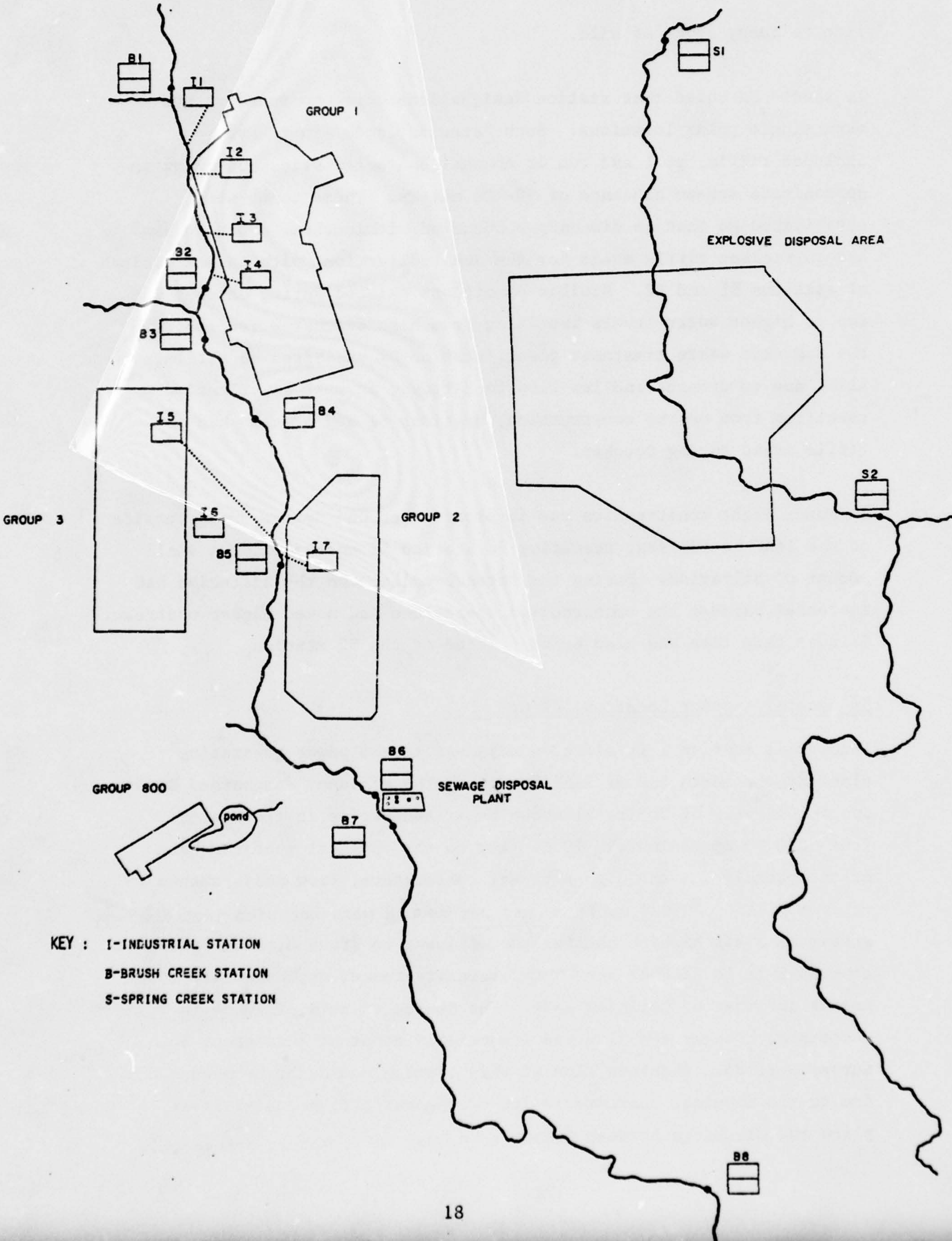
It should be noted that station designations refer to zones rather than single point locations. Such "station zones" in the stream included riffle, pool and run or channel characteristics, covering an approximate stream distance of 90-100 meters. These zones were established so that no discharges occurred within them. Most streams had sufficient riffle areas for the June collection, with the exceptions of stations B1 and B2. Similar conditions existed during October but due to higher water levels resulting from high discharge levels from the domestic waste treatment plant, station B7 exhibited no riffle. Also, due to drought and low flow conditions, as well as siltation resulting from nearby construction, stations S1 and S2 also had no riffle areas during October.

In June, light construction was in progress around Spring Creek outside of the IAAP boundaries, resulting in station S1 encountering a small amount of siltation. During the October collection the siltation had increased because the construction operations had moved closer upstream. Silt at this time was also being noticed at the S2 station.

Industrial Station Location (Figure 3)

Industrial station 1 is situated adjacent to the power generating plant at the north end of IAAP Group 1. The effluent discharged here consist largely of boiler blowdown water and varies in temperature from 30°C to approximately 70°C. Due to the physical configuration of the outfall and the high effluent temperature, flow measurements of from 0.015 to 0.020 cubic meters per second were recorded just downstream in a ditch which carries the effluent to Brush Creek. Industrial station 2 is located at the Group 1 security fence, approximately 1000 meters due west of building 1-04. The source of this effluent is uncertain, however the flow was essentially constant throughout both survey periods. Absolute flow at this station could not be measured due to the physical characteristics of the outfall, but estimates place the discharge between 0.0001 to 0.0003 cubic meters per second.

Figure 3. Schematic of Iowa Army Ammunition Plant Study Area - 1975.



Industrial station 3 is also located at the security fence of Group 1, approximately 1200 meters south of Industrial station 3 and 1000 meters west of the Group 1 TNT melt buildings. The effluent is believed to originate from these two facilities (Building 1-05-1 and 1-05-2). Again in this case, physical characteristics of the outfall precluded accurate measurement of the discharge, however the flow was estimated at from 0.0001 to 0.0003 cubic meters per second. Variations in the flow were observed during the two survey periods.

Industrial station 4 is situated approximately 700 meters south of station 3, along the Group 1 security fence. It empties almost directly into Brush Creek at a point 1000 meters due west of building 1-10. The effluent is thought to originate from TNT processing operations conducted in the south half of the Group 1 installation. The flow at this outfall varied significantly during both the summer and fall survey periods, with maximum observed discharges of from 0.0003 to 0.0005 cubic meters per seocond.

Industrial station 5 is located at the security fence of Group 3, 1000 meters due east of building 3-04. A flow of from less than 0.0001 cubic meters per second is believed to originate from the metal refinishing operations being conducted in buildings 3-01 and 3-04 of the Group 3 installation.

Industrial station 6 is located 1600 meters south of station 5, also along the security fence of Group 3. This station is intended to collect effluent from the carbon contact columns adjacent to buildings 3-05-1 and 3-05-2. No flow was ever observed during the two survey periods, apparently resulting from the inactivity of these two TNT melt facilities.

Industrial station 7 is situated at the security fence of Group 2, 700 meters west of building 2-05-2. The effluent at this outfall originates at the two carbon contact treatment facilities adjacent to the TNT melt buildings 2-05-1 and 2-05-2. The water discharged

here is primarily washdown water generated in the processing of explosives such as composition B and other TNT/RDX materials. The flow at this station was found to vary somewhat, with average values ranging from 0.0015 to 0.0017 cubic meters per second.

The industrial stations outlined above do not comprise all of the point and non-point source tributaries of Brush Creek within the IAAP boundary. They do, however, include all of the munitions related discharges which could be identified as potential sources of munitions compounds in this small stream. From Figure 3, it is evident that industrial outfalls 1 through 4 discharge to Brush Creek between stream stations B1 and B2. There are no known point source discharges containing munitions compounds between stream stations B3 and B4. Industrial outfalls 5 through 7 discharge to Brush Creek between B4 and B5. There are no known point source discharges of munitions compounds between B5 and B6. The IAAP sewage treatment plant discharges between B6 and B7, and there are no further known point source discharges of munitions compounds into Brush Creek to the IAAP plant boundary.

There are no known point source discharges of munitions bearing wastes upstream of station S2 on Spring Creek. The revised station scheme for the 1975 water quality survey was designed with reference to specific industrial waste outfalls. Survey criteria were in accordance to the objectives of Phase II - Parts 1 and 2 of the original proposal with minor revisions to investigate or characterize specific waste effluents. The following objectives were to be met:

Task 1. Physical/Chemical Survey - Conduct a point discharge (effluent) sampling program to characterize and evaluate the variability in the effluents during the period of the survey. Conduct a stream sampling program to characterize and evaluate the variability of stream water chemistry. Samples for analysis will be collected at or near the biological sampling stations to measure standard water quality and munitions compounds. Sediment samples were to be taken at the stream

sampling stations to determine the variability of munitions compounds and nutrients contained in the sediments. Stream stations will be physically characterized as to width, depth, flow, velocity, and sediment description.

Task 2. Periphyton - Conduct sampling at the stream stations to define and describe the variations in periphytic macrocommunities, limited to diatoms and filamentous algae, collected from both natural and artificial substrates. Variations in species associations, organic biomass, and chlorophyll a were to be described as they occurred between stream stations.

Task 3. Macroinvertebrates - Conduct sampling at the stream stations to define and describe the variations of the benthic macroinvertebrate communities. Both natural and artificial substrate collections were to be used to describe variations in population structure.

Task 4. ATP Measurements - The measurement of adenosine triphosphate (ATP) will be conducted on microbial communities of sediments and periphyton from artificial substrates. This is to be the initial approach to Phase II - Part 2 objectives in an effort to describe potential effects on primary productivity and microbial activity.

FIELD METHODOLOGY

Chemistry

The chemistry sampling program at the IAAP was designed to evaluate the impact of various munitions processing installations on the water quality of Brush Creek. To this end, eight sampling stations were set up along the stream and seven point source sampling stations were located at discharges of the industrial facilities adjacent to the stream. Two sampling stations were situated on Spring Creek to serve as controls for the Brush Creek stations since the upstream section of Brush Creek consists primarily of industrial process wastewater.

Each of the stream and industrial stations was sampled five times during

both the summer and fall survey periods. Sampling was conducted only during periods of production line operation. A summary of the production activities of each IAAP group is outlined in Table 1. It is noteworthy that according to IAAP personnel, plant operations were at approximately 10 percent of rated capacity. Thus, the impact of the processing installations on stream conditions are approaching the lowest that could exist without a full scale shutdown of the munitions processing parts of the plant.

Water samples were collected daily during the operation of the processing facilities but without regard for exact time of day. At each stream and industrial station, approximately four gallons of water was collected and composited in plastic buckets. The sample was then poured off into five subsample containers, one for each preservative to be used and a fifth for analyses to be performed immediately upon returning to the field laboratory. Temperature was recorded at the sampling site, although no deviation from ambient (i.e. approximately 25°C during the summer survey and 15°C during the fall survey) was observed at any station except industrial station 1. After pouring off the sample into the appropriate subsample vessles, all containers were stored in ice chests until received at the field laboratory.

IAAP contractor personnel kindly provided laboratory facilities for the summer and fall survey periods, so the analysis of samples for certain parameters was conducted immediately upon receipt of the samples from the field. These included pH, alkalinity, dissolved oxygen, BOD and specific conductance. Dissolved oxygen was measured within one hour of sampling, with the remaining analysis performed within four hours. A one liter polyethylene container which had been filled to exclude air space was used for these analyses. A second one liter polyethylene container filled to the brim was transported and stored at 4°C until analysis of total solids, total suspended solids, chloride, sulfate, hardness, sodium and potassium was completed in Ann Arbor. The subsample for trace metal analysis was stored in polyethylene and preserved by adding 10 ml reagent nitric acid per liter of sample. A 2.4 liter glass container was used to store the subsample for nutrient analysis. Reagent sulfuric acid was added at a concentration of 2 ml per liter of sample to

Table 1. INDUSTRIAL OPERATIONS AT IOWA ARMY AMMUNITION PLANT - JUNE 1975

Facility	Process Elements	Production Status
Group 1	Octol	Active
Group 2	Composition B, Octol	Active
Group 3	Composition B, Metal Processing	Active
Group 3A	Composition B	Active
Group 4	Assembly	Active
Group 5A	TNT	Active
Group 5B	(Not Available)	Inactive
Group 6	Detonators	Inactive
Group 7	Boosters, Black Powder	Inactive
Group 8	Fertilizer	Inactive
Group 9	Fuses, Black Powder	Active
Group 800	Composition B, Metal Processing	Active

inhibit biological activity and retard the transformation of nitrogen forms. This nutrient subsample was also transported and stored at $4^{o}C$ until all required analyses had been completed. The subsample for munitions compounds analysis was stored in four liter brown glass bottles with teflon lined caps. Upon receipt in the field laboratory, the samples were poured off to the 3.8 liter mark and 50 ml of benzene ("Distilled in Glass", Burdick and Jackson, Muskegon, MI) was added. The sample was then stirred for ten minutes at a sufficiently rapid rate to insure uniform dispersion of the benzene solvent. This procedure serves two purposes. First, biological alternation of the munitions compounds is inhibited due to the extreme biocidal character of benzene. Secondly, the munitions compounds and their benzene soluble transformation products are isolated from the aqueous phase, which retards chemical alternation of the compounds. After ten minutes of stirring, the sample was capped and prepared for shipping back to Ann Arobr, where the extraction procedure would be completed. As a further means of stabilizing the munitions compounds, all such partially extracted samples were transported and stored at $4^{o}C$ until the extraction procedure had been completed. All analyses and/or sample preparation and preservation were performed within four hours of actual sampling.

After the five daily water samplings had been gathered, and the preliminary water quality of the industrial effluents established, a diurnal sampling program was initiated in order to verify that the stream water quality did not vary significantly during the period when normal sampling was not performed. Automatic samplers* were placed at stream stations B1 and B8. Samples were taken once an hour for 48 hours. The samples were stored on ice inside the automatic sampler to minimize changes in water chemistry. They were collected by laboratory personnel and analyzed for pH and specific conductance every 12 hours. Since production at the IAAP was limited to the day and afternoon shifts during the two survey periods, and since the summer diurnal study confirmed that the water quality of Brush Creek did not change significantly during the period of no sampling activity, a diurnal study was not performed during the fall survey period.

*Sigmamotor™ varistaltic discrete samplers

Sediment samples were collected after all water sampling was complete. At the outset of the summer survey period a zone was marked off from which sediment samples were to be gathered. Care was taken to insure that these zones were not disturbed during other stream sampling. The same zones were used to gather sediments for both the summer and fall surveys. As a result of this, differences in sediment chemistry at a given station between summer and fall samplings may be interpreted as a change in the character of the stream bottom deposits.

Two inch diameter polycarbonate core tubes were used to gather all sediment samples. Each tube has air-tight end caps which are removed before pressing the transparent sleeve into the sediment. Once the tube has been pressed to the desired depth, the top is capped and the tube is withdrawn with core sample intact. The bottom is then capped and the sample is frozen. Three core samples were gathered from each stream station during each of the two survey periods. The cores were frozen with dry ice immediately after sampling and stored in this condition until analysis could begin.

Biology

Periphyton -

Collections of periphyton were taken from both natural and artificial substrates. The material collected from natural substrates was utilized for species identifications of diatom and non-diatom algae. Periphyton taken from artificial substrates was used for determination of species occurrence, ash-free dry weight, and chlorophyll concentration. Collecting periphyton from both natural and artificial substrates enabled the determination of the complete attached algal community and to identify the population available to colonize the artificial substrates.

Natural substrates - Sampling from natural substrates included the haptobenthos, i.e., solid surfaces such as submerged rocks and wood, and the herpobenthos, i.e., growths on mud or mud/sand surfaces[5]. The solid surfaces of rocks and wood were scraped with a pocket knife and

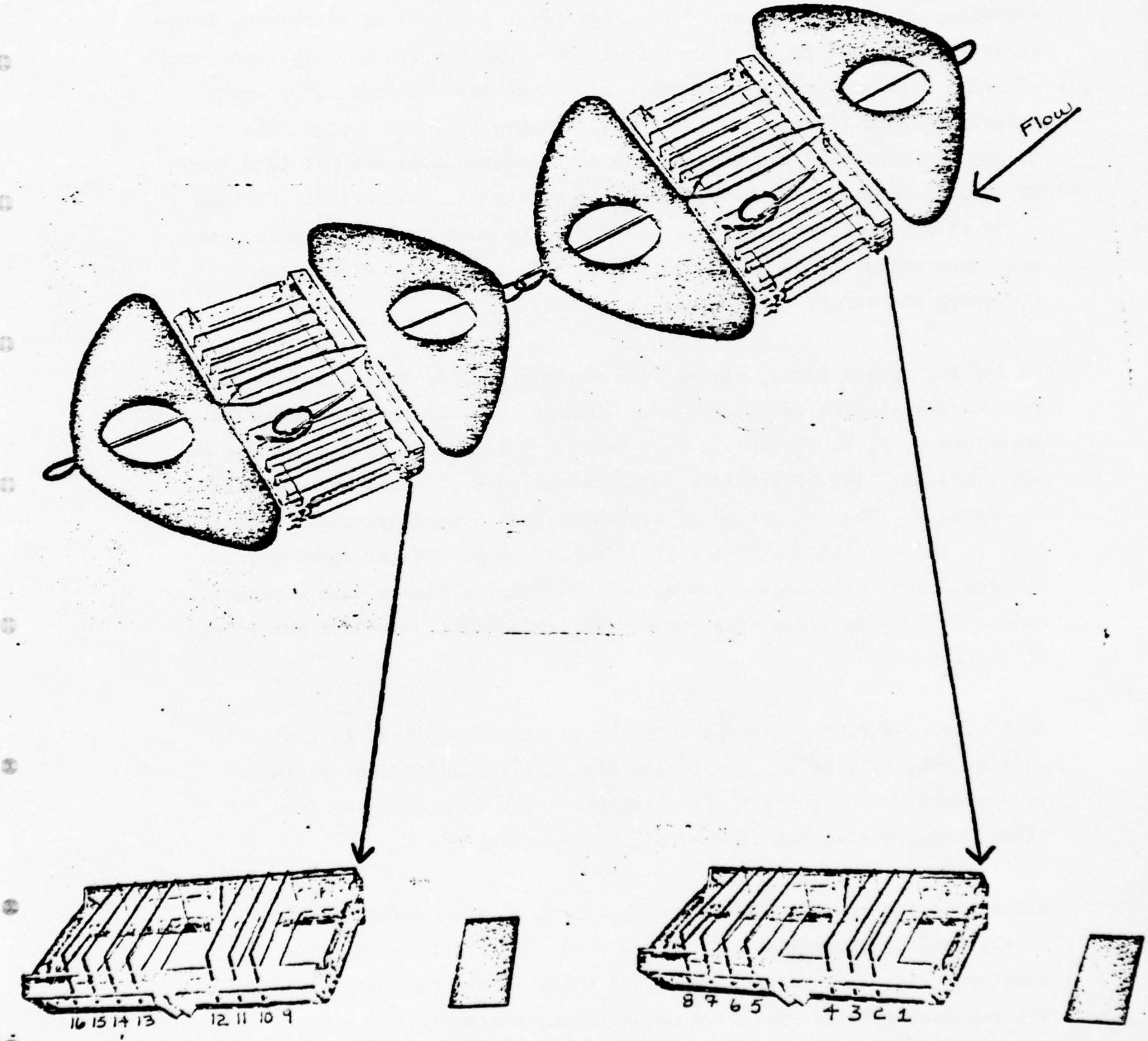
forceps and the material was placed in vials. Collections from rock surfaces and wood surfaces were treated independently from each other. Several submerged rock and wood surfaces were sampled as well as sampling all possible positions, sides, or areas of these substrates with reference to direction of flow and direction of sunlight. An attempt was made to sample all possible microhabitats on rock and wood surfaces. This was to insure a sample representative of the entire attached algal community and was an attempt to prevent the sole sampling of isolated microhabitats which may be dominated by a select species. Vials were appropriately labelled and the collections were preserved with a two percent formalin solution.

Material growing on the surface of sediments was collected by gently lifting the surface "film" or "floc" with a knife blade or by pipetting the "floc". Similar to sampling the haptobenthos many surfaces were collected to prevent the sampling of a single isolated species or species-complex which could inhabit a unique zone. Again the attempt was made to collect from all possible zones or areas of the herpobenthos. The pipets used for removing the "films" or "flocs" had a wide diameter opening to prevent size discrimination of periphytic organisms. Sediment surface samples were placed in single vial and preserved with a two percent formalin solution. Vials were appropriately labelled and the sample treated independently of the samples collected from rock and wood surfaces.

Artificial substrates - Artificial substrate samplers were used to achieve consistency between collections at the different stations and between different sampling periods. The artificial substrates guaranteed comparable surfaces for colonization as well as regulating the period of colonization and periphyton growth. Two substrate samplers, Periphytometers™*, were attached in tandem and each loaded with eight glass microscope slides, one inch by three inches in dimension (Figure 4). Slide positions were numbered to maintain a consistent sampling routine where slides from predetermined positions would be used

*manufactured by Design Alliance, Inc.

Figure 4. Schematic of Periphytometer
Showing Slide Position



as replicates for either species identifications, chlorophyll measurements, or dry weight determinations.

The tandem arrangement of Periphytometers™ was anchored at the stations by a light weight cable attached to a steel stake or cinderblock anchor, depending on water depth and flow conditions. A spherical styrofoam, lead-float was attached to the free end of the cable from which a six foot length of nylon rope was attached to the Periphytometers™. Sufficient cable length was used to accomodate possible changes in water depth. The incubation period of the samplers at each station site was not less than 30 days to permit sufficient periphyton growth for collection. Periods of 30-45 days were necessary to achieve sufficient periphyton mass, yet not approaching the stage of sloughing. The absence of significant sloughing was verified by visual observation.

During the spring survey slides from positions 2, 5, 8, 11, and 14 were removed for species identification. During the fall survey slides from positions 3, 6, 9, 12, and 15 were taken. This procedure was applied at all stations. The five slides were treated as replicates and compared accordingly. The collection of slides in this manner prevented a possible bias in the results due to the position in the artificial samplers, as the replicates were taken from all of the sampler rather than adjacent slides from an isolated area. Hopefully this routine reduced the effects of sampling error.

Each slide was gently removed from the sampler and placed in a plastic bottle. The samples were appropriately labelled and preserved in a two-percent formalin solution. Periphyton was later scraped from the slides and prepared for microscopic observation.

All periphyton material for the measurement of dry weight, ash-free dry weight, and chlorphyll was collected from the artificial substrate samplers. Samplers were prepared and anchored as previously discussed. The routine for slide position and collection was similar to that described for species occurrence. Five replicate slides were taken for both dry weight and chlorophyll measurements.

During the spring survey (May-June) slides were taken from positions 1, 4, 7, 10, and 13 and prepared for dry weight determinations. During the fall survey (October) slides were taken from positions 2, 5, 8, 11, and 14 (Figure 4). The slides were gently removed from the sampler and placed in separate plastic bottles. Samples were labelled and preserved in a two percent formalin solution. Periphyton was later scraped from the slides and prepared for dry weight determinations.

Samples for chlorophyll analysis were collected from slide positions 3, 6, 9, 12, and 15 during the spring survey. This order was changed to positions 1, 4, 7, 10, and 13 during the fall survey (Figure 4). Slides were gently removed from the samplers and placed in separate plastic bottles with distilled water. Samples were labelled and immediately put on ice to reduce biological activity and chlorophyll breakdown. Within two hours after collection, the periphyton was scraped from the slides and filtered onto 4.25 centimeter, 0.45 micron Whatman GF/C glass fiber filters. The material remaining in the bottle was also filtered onto the pad. The filters were folded and placed in labelled plastic petri dishes. These samples were immediately frozen in the dark and held for pigment extraction and analysis in the laboratory.

Material for ATP analysis of natural microcommunities was taken from periphyton artificial substrate samplers and sediment microcores. Glass microscope slides were incubated along with and for the same duration as slides used for other periphyton measurements. Slides were selected from predetermined positions in the samplers. Periphyton was scraped from the slides, filtered onto Whatman GF/C glass fiber mats (0.45 μ pore size) and rinsed with distilled water. Filters were then folded with filtrate on the inside, frozen on dry ice, and held for laboratory extraction and analysis of ATP.

Sediment microcores were taken with plastic disposable syringes (50 cc) from which the needle ends had been removed. This produced a six inch long coring device with sealed plunger to collect microcores from stream sediments. Microcores were taken from soft sediments, i.e., fine silt, detritus and ooze, near the stream banks at waters edge and from shallow pools. The cores were left inside the coring tube, placed in

plastic bags, sealed, and frozen on dry ice until ATP extraction and analysis at the laboratory.

Benthic Macroinvertebrates -

Collections of the benthic macroinvertebrate community were taken from both natural substrates and artificial substrate samplers. Species occurrence was determined from both substrate types. Because physical conditions of streams and rivers are often quite variable with distance between sampling locations, there is the potential problem of substrate limitation or variation when sampling benthic macroinvertebrate populations from natural substrates. In an effort to alleviate this problem, replicate artificial substrate samplers were used at all stations[6]. This provided a consistent substrate type for colonization and comparison. Collections made from the natural substrates provided information on background benthic populations available to colonize the artificial substrates.

Natural Substrates - Samples were collected from two basic substrate types at each station - sand/silt sediments of pool areas and stones and rocks of riffle areas.

Two replicate samples were taken from the pool areas of each station using a Petite Ponar™ with a sampling area of 36 square inches (232 square centimeters). These samples were washed in a Ponar Wash Frame which retains particles and organisms larger than 520 microns. Three replicate samples were taken from the riffle areas of each station using a Surber type square foot sampler. All samples were placed in appropriately labelled bottles and preserved with two-tenths (0.2) percent rose bengal solution in 80 percent isopropyl alcohol[7]. Samples were held until arriving at the laboratory where the organisms were picked and sorted. All samples were treated independently of each other.

Artificial substrates - Multiplate samplers (Hester-Dendy type)[8] constructed of nine, three inch by three inch (7.6 by 7.6 centimeters)

square, one-eighth inch (0.318 centimeters) thick, scored hardboard plates were used at all stations. The plates were assembled with one inch (2.54 centimeter) square, one-eighth inch (0.318 centimeters) thick hardboard spacers on one-square inch(0.635 centimeters), 15 inch (38 centimeters) long threaded rod. Five replicate multiplate samplers were set downstream from riffle areas at each station. Each sampler had a surface sampling area of 158.5 square inches (1022.6 square centimeters) yielding a total effective sampling area of about one-half (0.5) square meters. Samplers were permitted to colonize for a period of about 45 days.

Upon collection, the samplers were gently lifted from the stream bed and each was placed in a white enamel tray. The samplers were disassembled and placed in plastic freezer containers for transport to the field laboratory. Any organisms which may have been dislodged from the plates were picked from the trays and added to the respective containers. At the field laboratory the plates were brushed and washed, and the collected material washed in a No. 30 U. S. Standard sieve. Sample material was then placed in plastic bottles, labelled, preserved with a two-tenths (0.2) percent rose bengal solution in 80 percent isopropyl alcohol[7], and taken to the laboratory where the organisms were picked and sorted. All samples were treated independently of each other.

Incubation Periods of Artificial Substrates - Artificial substrate samplers for both periphyton and benthic macroinvertebrates were set for the spring survey on 13-14 May 1975. Samplers were collected during the survey period 19-27 June 1975 yielding an incubation period of 38 to 41 days. Exact length of incubation periods are given on appropriate tables in the subsequent results and discussion section.

Samplers were set on 9 September 1975 for the fall survey. These were collected on 13-14 October 1975 during the fall survey period allowing an incubation period of 34 and 35 days respectively.

SECTION VI

CHEMISTRY

ANALYTICAL PROCEDURES

Aqueous Phase

In order to evaluate the impact of the AAP on the receiving waters, an extensive characterization of the water quality of the receiving stream, as well as a characterization of the industrial effluents, was undertaken. The parameters monitored included the following:

Dissolved Oxygen	Suspended Solids
pH	Total Solids
Alkalinity	Chloride
Specific Conductance	Sulfate
Biological Oxygen Demand	Sodium
Chemical Oxygen Demand	Potassium
Total Organic Carbon	Hardness
Cadmium	Nitrate-N
Chromium	Nitrite-N
Iron	Ammonia-N
Lead	Kjeldahl-N
Manganese	Total Phosphorus
Mercury	Munitions Compounds

General Water Quality Parameters -
Sampling of the aqueous phase for these parameters has been described in a previous section of this report, however, some additional comments are noteworthy here. All sample containers had been acid-washed and rinsed with copious amounts of distilled water. As noted earlier, samples for metal analysis were preserved with reagent grade

nitric acid. Samples for nutrient, COD, and TOC analysis were preserved with reagent grade sulfuric acid and refrigerated. All other samples were preserved by refrigeration at $4^{o}C$ from the time of sampling to the completion of analysis in the laboratory.

In general, all methods of chemical analysis employed in the characterization of aqueous samples were taken from the three most widely accepted compilations of such procedures[10,11,12]. Where methods were unavailable or insufficient to provide the desired information, particularly with respect to munitions compounds, alternate analytical procedures were employed after their accuracy and precision had been statistically verified. A brief synopsis of the analytical methodology is contained in the following paragraphs.

Measurements of dissolved oxygen were made, both in the in situ stream determinations and in the analysis of biochemical oxygen demand, with a polarographic-type gas sensing probe which utilizes a semipermeable fluorocarbon membrane. Hydrogen ion concentration was measured with a glass membrane/calomel combination electrode and digital pH meter capable of 0.01 unit resolution. This appartus was also used in the standard acid titration for alkalinity. Chloride ion concentration was determined by a method adapted from the fluoride ion slective electrode method listed in the EPA manual[10]. A chloride ion slective electrode from Corning Scientific Instruments (model 476126) was used in conjunction with a silver/silver chloride reference electrode. The reference cell was fitted with a seondary salt-bridge containing 1.0 M potassium nitrate to prevent chloride bleed into the sample solution. Calibration of the device was accomplished by standard addition in order to compensate for matrix and temperature effects. Sulfate ion concentration was determined by the barium sulfate suspension technique outlined in the EPA reference[10]. Suspended solids were measured using Millipore AP40 glass fiber mats, pressure filtration and drying to constant weight at $105^{o}C$. Total solids were measured by evaporating a 100 ml aliquot of sample to dryness at $105^{o}C$.

Biological oxygen demand in the AAP water samples was measured according to the serial dilution procedure specified in APHA Standard Methods[11]. The samples were set on the same day as collected, and incubated for

five days. Chemical oxygen demand was determined by the dichromate/sulfuric acid digestion method. The oxidant was 0.025 N dichromate, providing an effective detection limit of approximately 5 mg/l. Consumption of the oxidant was measured spectrophotometrically. Total organic carbon was determined using an Oceanography International total carbon system. With this system, an aliquot of acidified sample is sealed in a 10 ml ampule containing persulfate and digested overnight in a pressure vessel at 175°C. The persulfate oxidizes the organic carbon to CO_2. The ampules are broken and the CO_2 flushed through an infrared detector interfaced with a digital integrator.

Nitrogen was measured in four forms in the aqueous phase. Nitrate-nitrogen was reacted with brucine sulfate in acidic media to produce a colored complex which was measured spectrophotometrically. Nitrite-nitrogen was similary determined, though in this case the colored complex results from the diazo coupling of sulfanilic acid and naphthylamine hydrochloride in the presence of nitrite and excess hydrogen ions. Reduced nitrogen forms were determined by the Kjeldahl method. This method employs a mercury catalyzed sulfuric acid digestion followed by distillation into boric acid and a potentiometric endpoint titration. Ammonia concentrations were measured with a potentiometric-type gas sensing probe. Determination of ammonia with this device is now an accepted EPA procedure[10]. Evaluation of the ammonia probe by the U.S. Environmental Protection Agency and by exhaustive tests in our own laboratory reveals it to be equal in accuracy and precision to the indophenol blue method commonly employed for low levels of ammonia.

Total phosphorus levels in the aqueous phase were determined on the whole-water samples after a persulfate/sulfuric acid digestion. The digestate was subjected to analysis using either the ascorbic acid or vanadomolybdophosphoric acid technique outlined in the APHA water analysis manual, depending on the phosphorus level.

Metal analysis of the aqueous phase was accomplished by atomic absorption spectrophotometry. Total concentrations of the metals cadmium, chromium, iron, lead, manganese, and mercury were determined in the acidified water samples. Calcium and magnesium where determined on filtered water samples. High temperature flameless AAS was employed for all metals except calcium,

iron, magnesium, and mercury[12]. Mercury was analyzed using the cold vapor atomic absorption technique developed by Hatch and Ott[13]. Calcium, iron and magnesium were analyzed using conventional air-acetylene flame AAS[10,11]. Calcium and magnesium values so determined were used to calculate hardness[11]. The method of standard addition was utilized whenever necessary to compensate for matrix effects on instrument calibration. Sodium and potassium were determined by flame emission spectrophotometry.

Munitions Compounds -
Analysis of AAP water samples for munitions compounds followed closely the analytical methodology of the 1974 study[14]. The benzene layer in the water samples brought back from the field was removed and each sample was re-extracted with two additional 50 ml aliquots of benzene. The combined extract from each sample was dried with anhydrous sodium sulfate and concentrated to approximately 5 ml by passing nitrogen over the liquid surface while heating the extract on a water bath. The 5 ml concentrate was administered to the top of a 1 cm by 7 cm high column of fully activated silica gel (Davison grade 923). The column was wet packed in benzene. One hundred milliliters of 20 percent (v/v) ethyl ether in benzene was used to elute the components of interest. Studies conducted last year indicated that under these conditions, compounds with base character less than or equal to aminodinitrotoluene would be eluted in this cleanup. This includes such compounds as the mononitrotoluenes, dinitrotoluenes, trinitrotoluenes, mono-, di - and trinitrobenzenes, tetranitroazoxytoluenes, hydroxylaminodinitrotoluenes and the two monoamino reduction products of TNT. It should be noted here that the diamino transformation products, as well as other polyamines, would not be recovered in this cleanup procedure.

The elutriate is collected and concentrated using the previously described procedure to less than 5 ml. At this point the concentrate is transferred to a 5 ml vial and the extract is taken to dryness. The sample extract is stored in this condition at $-20^{o}C$ until analysis by vapor phase chromatography (VPC). At such time, the extract is taken up in a predetermined

volume of benzene and an aliquot of this concentrate is administered to the gas chromatograph.

The VPC system used for this study is somewhat different than that used in 1974[11]. Several researchers have reported that 1, 3, 5 - trinitrobenzene is an important photolysis product of 2, 4, 6, - TNT[14,15]. As a consequence, it was deemed important to be able to differentiate 2, 4, 6 - TNT from 1, 3, 5 - TNB in the environment. In investigating the applicability of the existing extraction/cleanup method for TNB analysis, it was learned that a 5 percent Dexsil 300 liquid phase could not chromatographically resolve, 2, 4, 6 - TNT from 1, 3, 5- TNB, despite numerous manipulations of chromatographic conditions. A 10 percent liquid loading of G.C. grade SE-30 was found to resolve these two compounds and still provide adequate chromatographic characteristics for the other munitions-related compounds of interest. The chromatographic system employed for these analyses is detailed in Figure 5. The resolution capability of this VPC system is shown in Figure 6. Chromatograms of representative water and sediment extracts appear in Figures 7 and 8, respectively.

A recovery study performed on the extraction/cleanup/VPC analysis system described above confirmed that the method is essentially quantitative for 2, 6 - dinitrotolune, 2, 4 - dinitrotoluene, 1, 3, 5, - trinitrobenzene 2, 4, 6 - trinitrotoluene, and 4 - hydroxylamino - 2, 6 - dinitrotoluene, with recovery efficiencies ranging from 95 to 100 percent. Data from the recovery study is presented in Appendix XX.

It should be noted here that although cyclotrimethylene trinitromine (RDX) and, to a lesser extent, cyclotetramethylene tetranitramine (HMX) are processed at the IAAP as co-explosives with alpha TNT, in mixtures such as composition B and Octol, only 5 mg of each compound was available from the Army for use in analytical method development and as quantitative standards for sample analysis. Such quantities were insufficient even for adequate method development and verification, so RDX and HMX were deleted from the list of organic compounds under study during the current project.

FIGURE 5. ANALYTICAL SYSTEM FOR VAPOR PHASE CHROMATOGRAPHY USING SE-30 COLUMN

INSTRUMENT	VARIAN 1860
INJECTION	ON COLUMN
SAMPLE SIZE	4 μl
COLUMN	
LENGTH	180 cm
O.D.	3 mm
COATING	G.C. SE-30
LOADING	10% (w/w)
SUPPORT	HP CHROMOSORB W AW-DMCS
MESH	80/100
CARRIER GAS	NITROGEN (LINDE UHP)
FLOW	40 ml per minute
DETECTOR	HYDROGEN FLAME IONIZATION

TEMPERATURE CONDITIONS

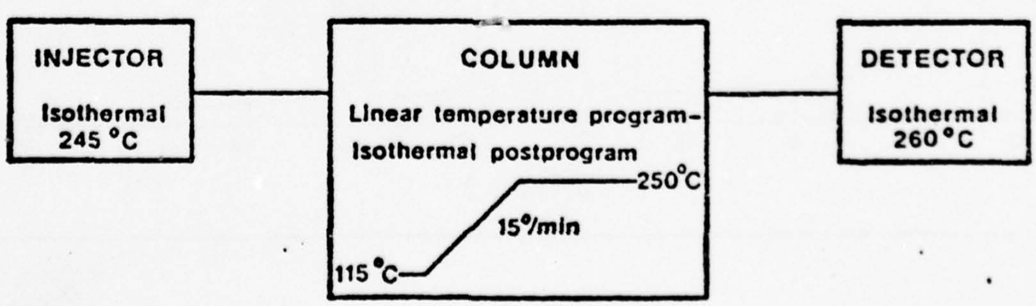


FIGURE 6. VPC RESOLUTION OF MUNITIONS RELATED COMPOUNDS USING SE-30 COLUMN

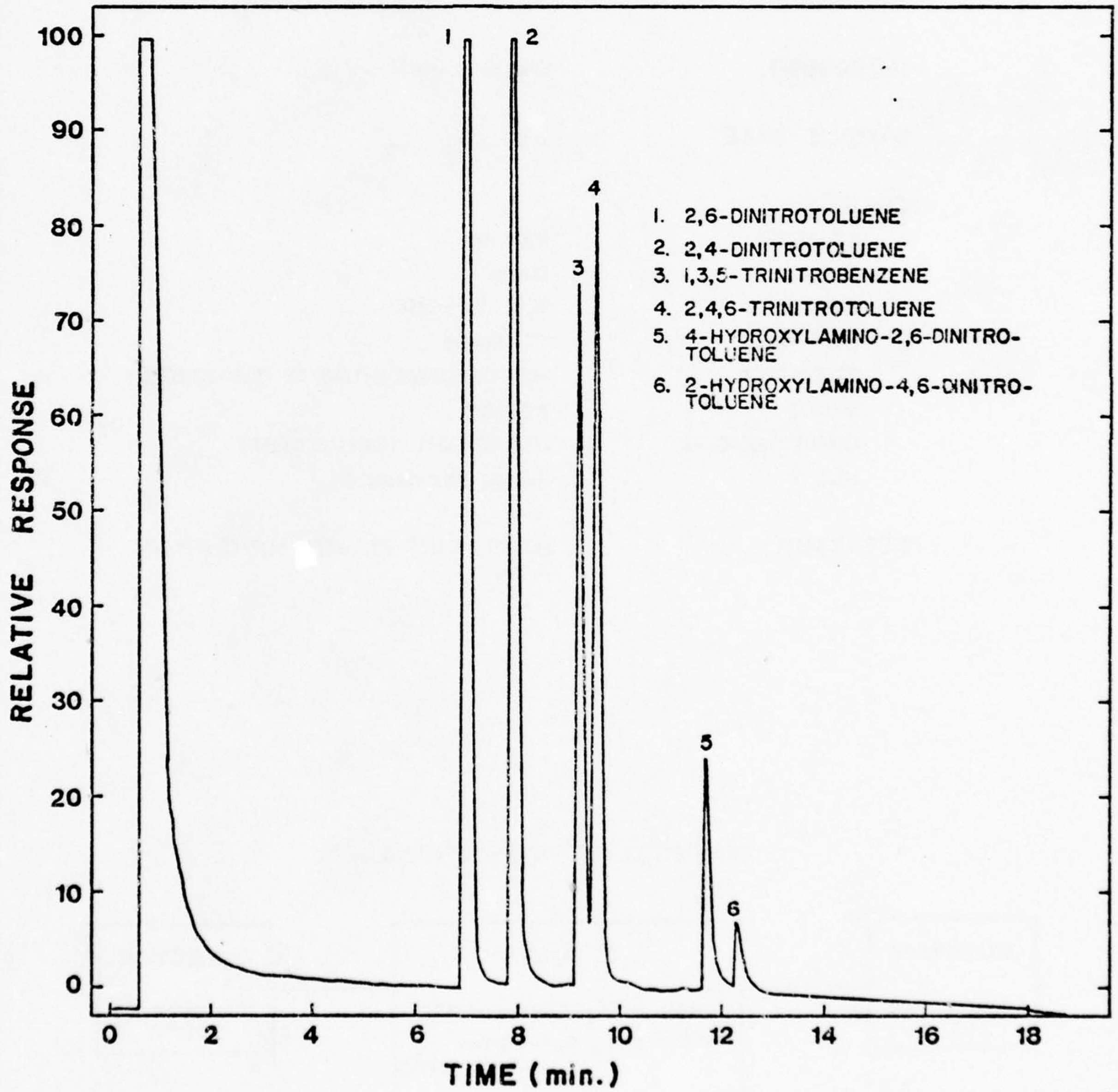
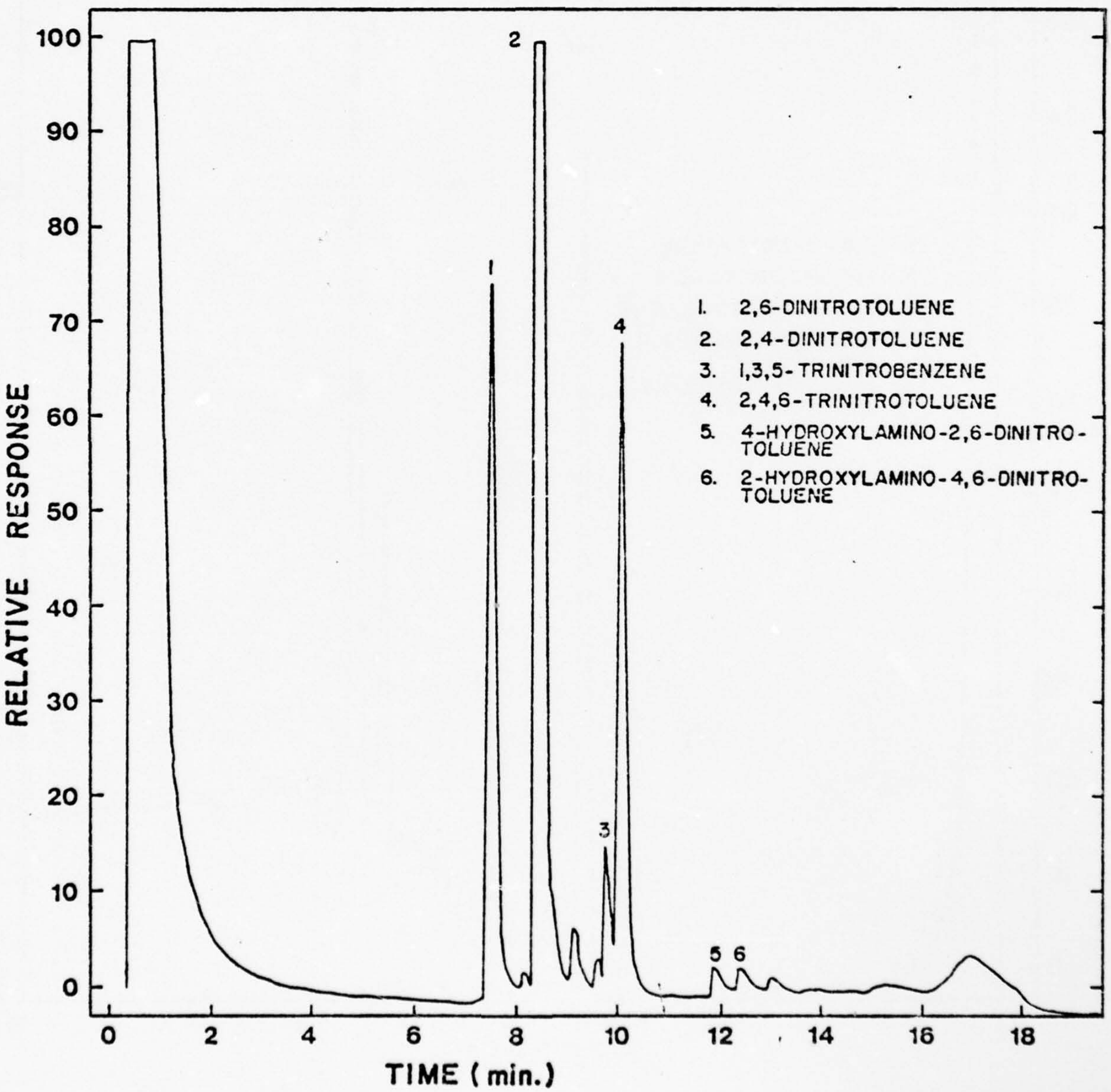


FIGURE 7. VPC RESOLUTION OF COMPONENTS IN TYPICAL WATER EXTRACT



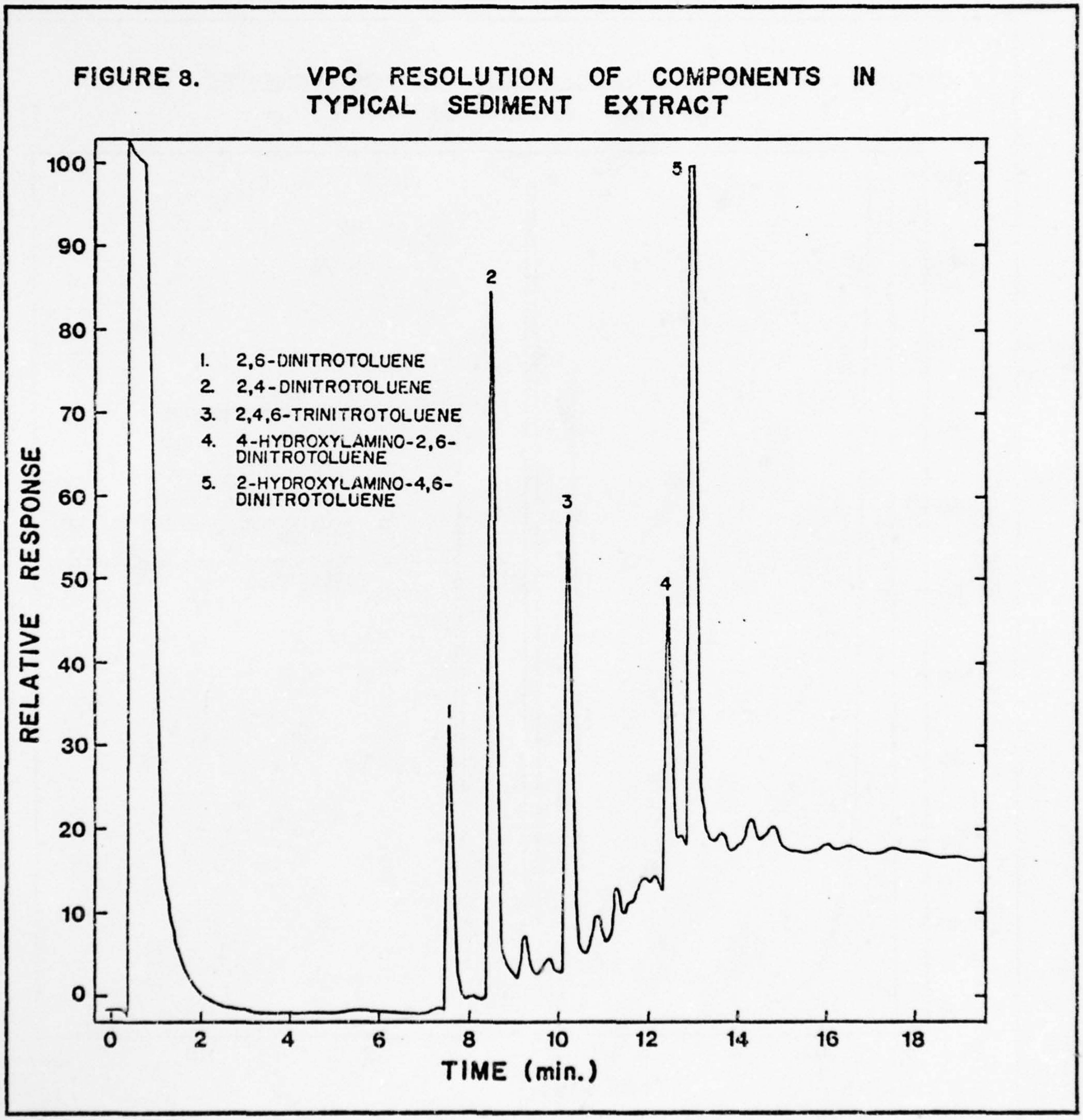


FIGURE 8. VPC RESOLUTION OF COMPONENTS IN TYPICAL SEDIMENT EXTRACT
RELATIVE RESPONSE
TIME (min.)
1. 2,6-DINITROTOLUENE
2. 2,4-DINITROTOLUENE
3. 2,4,6-TRINITROTOLUENE
4. 4-HYDROXYLAMINO-2,6-DINITROTOLUENE
5. 2-HYDROXYLAMINO-4,6-DINITROTOLUENE
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
1
2
3
4
5

Sediment Phase

Sampling of the sediment phase at the AAP has been described in an eariler section of this report. The samples were thoroughly frozen when received from the field and were stored in this condition until processing commenced. Freezing sediment material often disrupts the mineral morphology, but it was felt that the analyses to be performed on these samples would not be adversely affected and the low temperature preservation would minimize the decomposition of any munitions-related compounds present. The following parameters were determined on the sediment samples:

Total Solids	Cadmium
Total Volatile Solids	Chromium
Chemical Oxygen Demand	Iron
Hexane Extractables	Lead
Kjeldahl Nitrogen	Manganese
Nitrate+Nitrite Nitrogen	
Mercury	Total Phosphorus
Munitions Compounds	

General Sediment Parameters -
The sediment samples were thawed for processing and extruded from the polycarbonate core liners. Physical descriptions were made immediately and the core samples were sectioned according to depth from the water/sediment interface. For the present study, the upper 10 cm section was isolated, weighed and dried to constant weight at 50^{o}C. Where cores were of sufficient depth, additional 10 cm sections were also isolated and processed. After dry weights were recorded, all sediment samples were ground with a mortar and pestle and sieved through a 20 mesh screen (particles less than 841 micrometers). The weight fraction retained by the sieve was recorded and this fraction was excluded from the chemical analyses. Methods of chemical analysis for sediment characterization were taken primarily from the EPA reference "Chemistry Laboratory Manual: Bottom Sediments"[16]. A brief description of the procedures employed follows.

The analysis of carbonaceous material in the sediments included the determination of COD using the potassium dichromate-sulfuric acid digestion method. Volatile solids were determined by ashing the samples at 575°C for four hours. Hexane extractable materials were also determined in the dried sediment. Hexane served as the solvent in a four hour soxhlet extraction. The solvent was evaporated from the final extract and the residue was measured gravimetrically.

Reduced nitrogen forms in the sediment phase were determined by the Kjeldahl digestion/distillation/titration technique. Nitrate was analyzed as an indicator of oxidized nitrogen forms. In this analysis the nitrate was leached from the sediment by refluxing in dilute acid media. Since nitrite is converted to nitrate during the acid reflux, the results of this test actually indicate nitrate plus nitrite nitrogen. The leachate was then filtered and reacted with brucine sulfate under the controlled temperature conditions of the brucine method. The resultant colored complex was related spectrophotometrically to known standards. The third major biological nutrient, phosphorus, was measured in the sediments with the vanadomolydophosphoric acid test after the samples had undergone a persulfate/sulfuric acid digestion[11,16].

Sediment samples for metal analysis, with the exception of mercry, were prepared by dry ashing at 575°C for four hours, acid leaching the residue with a nitric acid/hydrogen perioxide solution, and removing the undissolved residue by titration The filtrate was analyzed for cadmium, chromium, iron, lead, and manganese using conventional air-acetylene flame atomic absorption spectrophotometry[16,17]. Mercury analysis was performed on samples prepared by wet digestion[18]. The finely divided samples were allowed to react overnight with fuming nitric acid and potassium dichromate. After digestion was complete, the excess dichromate was reduced with hydroxylamine hydrochloride. Reduction of the mercury with stannous chloride was followed by detection of the resulting elemental mercury using the cold vapor atomic absorption method[13].

Munitions Compounds -

Sediment samples were air dried at $50^{\circ}C$ specifically to retard thermal degradation of munitions-related compounds. Twenty grams of the ground and sieved sediment samples were extracted with benzene in a Soxhlet extractor for four hours, after which the extract was concentrated and cleaned up according to the method outlined in the aqueous phase section. Analysis of the extract by vapor phase chromatography was also essentially the same as for the water samples, though the solvent make-up volumes and the amount introduced into the gas chromatograph were adjusted to compensate for the greater amount of matrix material (primarily oils) found in the sediment extracts. Spiked samples were used to verify quantitative recovery (95-100%) of the compounds of interest.

RESULTS AND DISCUSSION

Aqueous Phase

General Water Quality -

Mean values for general water quality parameters for each survey period are presented in Table 2 through 7 (individual results from each daily sample can be found in the appendices). These concentrations represent average values of the five samples gathered during a survey period. Where levels are below the analytical detection limits in all five daily samples, the mean value appears as a "less than" number in the tables. Where one or more of the daily samples had detectable concentrations, the "less than" values were averaged as if the component of interest had been observed at the detection limit (e.g. in this case <0.001 would be averaged as 0.001). This allows differentiation of those stations where no detectable quantities were found from other stations at which analysis of one or more daily samples revealed detectable quantities of the component of interest. Thus, throughout the chemistry section of this report, where a "less than" sign is observed in the table of mean values or table of statistical values related to mean values such as standard deviation, the indication is clear that no concentrations of the component of interest were detected in any of the samples taken at a given station during a given survey period.

Table 2 . AQUEOUS PHASE CHEMICAL DATA
IOWA ARMY AMMUNITION PLANT JUNE 1975
BRUSH CREEK STATIONS - MEANS

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
Specific Conductance	mhos/cm	520	740	720	630	550	870	670	570
Total Solids	mg/l	355	476	467	412	382	566	428	365
Total Suspended Solids	mg/l	31	13	14	8	17	4	7	3
pH	SU*	8.25	9.30	9.30	9.30	9.10	8.80	8.60	8.90
Total Alkalinity	mg/l as $CaCO_3$	184	153	153	152	131	141	133	145
Chloride	mg/l	37.1	109	97.3	72.8	58.6	162	110	68.8
Sulfate	mg/l	38	73	71	71	61	61	61	60
Total Hardness	mg/l as $CaCO_3$	280	159	164	151	149	194	181	185
Calcium	mg/l	65.9	33.7	35.0	34.1	33.9	42.0	38.8	42.9
Magnesium	mg/l	28.2	18.2	18.6	16.1	15.7	21.8	20.6	19.1
Sodium	mg/l	12	80	99	84	61	105	70	45
Potassium	mg/l	0.5	2.5	2.8	3.2	3.1	4.2	4.8	4.0
Dissolved Oxygen	mg/l	8.5	8.4	8.2	8.6	8.4	8.5	9.2	10.2
BOD	mg/l	2	2	1	2	4	2	4	2
COD	mg/l	8	14	14	23	18	10	15	10
TOC	mg/l	4	15	25	16	10	12	9	6
Kjeldahl-N	mg/l	0.8	0.7	0.7	0.8	2.0	0.6	0.9	0.5
Ammonia-N	mg/l	0.084	0.083	0.11	0.12	1.5	0.11	0.42	0.075
Nitrite-N	mg/l	0.028	0.009	0.010	0.016	0.11	0.010	0.008	0.005
Nitrate-N	mg/l	3.6	4.1	3.7	3.2	4.3	2.4	4.6	4.1
Total Phosphorus	mg/l	0.073	0.58	0.56	0.52	0.47	0.59	0.94	0.72

Table 2 (continued).

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
Cadmium	mg/l	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	mg/l	0.005	0.163	0.122	0.095	0.044	0.042	0.042	0.013
Iron	mg/l	1.13	0.58	0.65	0.41	0.091	0.32	0.48	0.25
Lead	mg/l	0.003	0.003	0.003	0.002	0.003	0.002	0.003	0.002
Manganese	mg/l	0.154	0.115	0.111	0.063	0.135	0.035	0.086	0.028
Mercury	mg/l	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0007	0.0001

*Median Value

Table 3. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
SPRING CREEK STATIONS-MEANS
JUNE 1975

		Station	
Parameter	Units	S1	S2
Specific Conductance	μmhos/cm	520	510
Total Solids	mg/1	321	334
Total Suspended Solids	mg/1	8	31
pH	SU	8.50*	8.40*
Total Alkalinity	mg/1 as $CaCO_3$	193	198
Chloride	mg/1	45.5	35.3
Sulfate	mg/1	37	38
Total Hardness	mg/1 as $CaCO_3$	260	258
Calcium	mg/1	61.7	62.7
Magnesium	mg/1	25.7	24.7
Sodium	mg/1	24	21
Potassium	mg/1	1.5	2.2
Dissolved Oxygen	mg/1	9.0	9.7
BOD	mg/1	2	2
COD	mg/1	10	12
TOC	mg/1	5	6
Kjeldahl-N	mg/1	0.5	0.6
Ammonia-N	mg/1	0.069	0.11
Nitrite-N	mg/1	0.034	0.012
Nitrate-N	mg/1	1.1	0.73

Table 3. Continued

Parameter	Units	Station S1	Station S2
Total Phosphorus	mg/l	0.13	0.13
Cadmium	mg/l	0.0003	0.0002
Chromium	mg/l	0.005	0.010
Iron	mg/l	0.32	0.53
Lead	mg/l	<0.001	0.003
Manganese	mg/l	0.111	0.149
Mercury	mg/l	<0.0001	<0.0001

*Median value

Table 4. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATIONS-MEANS
JUNE 1975

		Station					
Parameter	Units	I1	I2	I3	I4	I5	I7
Specific Conductance	µmhos/cm	8290	440	411	303	348	352
Total Solids	mg/l	6380	299	275	179	238	225
Total Suspended Solids	mg/l	130	9	4	3	15	11
pH	SU	10.95*	7.75*	7.95*	8.30*	7.65*	7.75*
Total Alkalinity	mg/l as$CaCO_3$	327	118	126	124	91	98
Chlroide	mg/l	2620	37.5	27.5	16.2	30.1	30.9
Sulfate	mg/l	215	51	45	21	39	38
Total Hardness	mg/l as $CaCO_3$	780	180	181	154	145	160
Calcium	mg/l	25.9	38.7	39.7	38.4	28.8	34.4
Magnesium	mg/l	170	20.6	20.0	14.4	17.8	18.0
Sodium	mg/l	1560	29	24	12	23	22
Potassium	mg/l	37.0	2.5	2.7	1.1	2.5	2.5
Dissolved Oxygen	mg/l	7.0	7.5	7.6	8.3	7.6	7.5
BOD	mg/l	15	2	2	1	2	5
COD	mg/l	57	13	7	39	16	32
TOC	mg/l	24	8	15	5	7	5
Kjeldahl-N	mg/l	1.2	0.7	0.6	0.4	0.8	5.1
Ammonia-N	mg/l	0.075	0.076	0.080	0.075	0.083	4.1
Nitrite-N	mg/l	0.009	0.005	0.003	0.004	0.005	0.15
Nitrate-N	mg/l	14	2.7	2.0	2.5	2.5	8.0

Table 4. Continued

Parameter	Units	Station					
		I1	I2	I3	I4	I5	I7
Total Phosphorus	mg/l	5.4	0.16	0.074	0.091	0.82	0.048
Cadmium	mg/l	0.0024	0.0001	0.0002	0.0001	0.0001	0.0003
Chromium	mg/l	0.010	0.003	0.420	0.052	0.003	0.005
Iron	mg/l	0.38	0.32	0.16	0.20	0.34	0.43
Lead	mg/l	0.017	0.005	0.001	0.001	0.001	0.001
Manganese	mg/l	0.055	0.160	0.072	0.120	0.059	0.170
Mercury	mg/l	0.0006	0.0002	0.0001	<0.0001	<0.0001	<0.0001

*Median value

Table 5 . AQUEOUS PHASE CHEMICAL DATA
IOWA ARMY AMMUNITION PLANT OCTOBER 1975
BRUSH CREEK STATIONS - Means

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
Specific Conductance	mhos/cm	1500	1040	1100	1060	1200	950	640	700
Total Solids	mg/l	1480	789	776	724	854	711	469	486
Total Suspended Solids	m/gl	40	17	5	2	7	7	46	3
pH	SU*	6.60	9.35	9.25	9.35	8.60	8.40	8.20	8.10
Total Alkalinity	mg/l as $CaCO_3$	146	153	159	162	153	160	135	155
Chloride	mg/l	25.7	241	234	258	353	209	109	136
Sulfate	mg/l	870	98	100	100	96	96	67	77
Total Hardness	mg/l as $CaCO_3$	890	229	213	204	236	206	185	223
Calcium	mg/l	200	45.1	40.7	38.2	42.0	38.6	37.4	47.2
Magnesium	mg/l	95	28.2	27.2	26.4	31.9	26.7	22.4	25.7
Sodium	mg/l	34	172	176	170	187	142	75	86
Potassium	mg/l	3.4	10.6	10.2	10.6	11.5	10.6	7.6	8.8
Dissolved Oxygen	mg/l	6.2	8.4	8.5	9.4	9.4	10.3	9.4	9.4
BOD	mg/l	2	3	2	2	2	3	2	2
COD	mg/l	14	18	19	20	17	21	11	14
TOC	mg/l	6	7	8	6	7	6	6	5
Kjeidahl-N	mg/l	0.8	0.9	0.8	0.8	0.7	0.7	0.9	0.7
Ammonia-N	mg/l	0.44	0.24	0.28	0.22	0.15	0.043	0.086	0.032
Nitrite-N	mg/l	0.003	0.005	0.007	0.005	0.008	0.007	0.004	0.007
Nitrate-N	mg/l	0.092	0.40	0.30	0.21	0.45	1.1	3.1	1.5

Table 5 (continued).

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
Total Phosphorus	mg/1	0.030	0.71	0.77	0.75	1.6	3.7	2.2	1.6
Cadmium	mg/1	-	-	-	-	-	-	-	-
Chromium	mg/1	0.001	0.108	0.058	0.034	0.029	0.058	0.026	0.017
Iron	mg/1	-	-	-	-	-	-	-	-
Lead	mg/1	0.008	0.002	0.001	0.001	0.001	< 0.001	< 0.001	< 0.001
Manganese	mg/1	-	-	-	-	-	-	-	-
Mercury	mg/1	-	-	-	-	-	-	-	-

*Median Value

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 6. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
SPRING CREEK STATIONS - MEANS
OCTOBER 1975

Parameter	Units	Station S1	S2
Specific Conductance	µmhos/cm	690	530
Total Solids	mg/1	529	373
Total Suspended Solids	mg/1	30	5
pH	SU	7.80*	7.80*
Total Alkalinity	mg/1 as $CaCO_3$	264	252
Chloride	mg/1	90.8	40.9
Sulfate	mg/1	49	57
Total Hardness	mg/1 as $CaCO_3$	365	298
Calcium	mg/1	81.5	70.2
Magnesium	mg/1	39.4	29.9
Sodium	mg/1	36	35
Potassium	mg/1	9.2	5.2
Dissolved Oxygen	mg/1	6.1	8.0
BOD	mg/1	11	3
COD	mg/1	40	12
TOC	mg/1	9	6
Kjeldahl-N	mg/1	0.9	0.5
Ammonia-N	mg/1	0.053	0.067
Nitrite-N	mg/1	0.006	0.006
Nitrate-N	mg/1	0.076	0.063

Table 6. Continued

Parameter	Units	Station S1	Station S2
Total Phosphorus	mg/l	0.40	0.15
Cadmium	mg/l	--	--
Chromium	mg/l	0.001	0.001
Iron	mg/l	--	--
Lead	mg/l	<0.001	0.001
Manganese	mg/l	--	--
Mercury	mg/l	--	--

*Median value

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 7. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATIONS-MEANS
OCTOBER 1975

		Station					
Parameter	Units	I1	I2	I3	I4	I5	I7
Specific Conductance	µmhos/cm	2180	362	388	292	376	358
Total Solids	mg/1	1200	224	271	197	321	230
Total Suspended Solids	mg/1	172	8	2	6	10	5
pH	SU	10.85*	7.90*	7.80*	7.90*	6.70*	7.95*
Total Alkalinity	mg/1 as $CaCO_3$	411	114	115	100	72	115
Chloride	mg/1	337	43.5	59.6	36.9	39.6	42.9
Sulfate	mg/1	240	45	60	36	52	51
Total Hardness	mg/1 as $CaCO_3$	35	160	170	136	145	166
Calcium	mg/1	9.2	32.9	32.1	29.6	26.5	33.4
Magnesium	mg/1	2.8	19.0	21.8	15.0	19.3	20.1
Sodium	m/gl	369	37	39	32	48	35
Potassium	mg/1	18.4	4.4	8.5	5.0	4.7	4.0
Dissolved Oxygen	mg/1	7.0	8.9	8.1	8.9	8.3	8.6
BOD	mg/1	20	1	3	1	1	1
COD	mg/1	74	8	12	12	9	6
TOC	mg/1	16	4	6	4	6	4
Kjeldahl-N	mg/1	1.3	0.4	1.1	0.5	0.6	0.4
Ammonia-N	mg/1	0.062	0.050	0.60	0.068	0.18	0.083
Nitrite-N	mg/1	0.001	0.003	0.017	0.005	0.003	0.057
Nitrate-N	mg/1	0.67	0.11	0.49	0.38	5.2	0.56

Table 7. Continued

Parameter	Units	Station I1	I2	I3	I4	I5	I7
Total Phosphorus	mg/l	8.2	0.11	0.71	1.1	32	0.042
Cadmium	mg/l	--	--	--	--	--	--
Chromium	mg/l	0.075	0.003	0.397	0.005	0.618	0.002
Iron	mg/l	--	--	--	--	--	--
Lead	mg/l	0.007	0.001	0.002	0.001	<0.001	<0.001
Manganese	mg/l	--	--	--	--	--	--
Mercury	mg/l	--	--	--	--	--	--

*Median value

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

A review of Tables 2 and 3 reveals that during the summer sampling the water quality of Brush Creek at stations B2 through B8 was affected by environmentally significant enrichment in two general areas: 1) major dissolved solids; and 2) biostimulating nutrients. Increases in chloride, sulfate, sodium, and to a lesser degree potassium and hardness were responsible for an average dissolved solids burden in this reach of Brush Creek which was approximately 30 percent higher than at station B1 and the Spring Creek control stations. Average concentrations of carbon, reduced and oxidized forms of nitrogen, and total phosphorus were also higher in this stretch of Brush Creek. The high concentrations of total phosphorus and nitrate-nitrogen were especially notable. Although no particular problems concerning BOD and dissolved oxygen were observed during the June survey, the low hydrogen ion concentrations measured during this period are considered significant modifications of the basic water quality of such a stream. Of the trace metals determined, only chromium was found to be significantly different from background conditions. The average values of 0.163, 0.122 and 0.095 mg/l at stations B2, B3 and B4,respectively,are considered high by normal freshwater stream standards.

The mean values for analyses performed on the industrial samples collected during June 1975 are presented in Table 4. Reviewing this information results in the inescapable conclusion that the effluent discharged at industrial station 1 has by far the greatest effect on general water quality in Brush Creek of any of the discharges surveyed. The level of most parameters measured are substantially higher here than the natural background conditions, and since flow at this station is at least an order of magnitude higher than the other industrial outfalls, this discharge may well be the largest source of non-munitions pollutants in the Brush Creek system. During the June survey, each of the other industrial outfalls were found to discharge one or more dissolved constituents at concentrations substantially higher than background stream levels. Industrial stations 2 and 5 discharged somewhat elevated concentrations of nitrate-nitrogen and total phosphorus.

Industrial station 3 was found to be a source of nitrate-nitrogen and chromium. Industrial station 4 discharged elevated levels of nitrate-nitrogen and chemical oxygen demanding (COD) materials. The effluent at outfall 7 contained relatively high concentrations of ammonia-, nitrite- and nitrate-nitrogen as well as COD materials.

Mean values for general water quality parameters measured during the fall survey period are presented in Tables 5 through 7. The trends observed in Brush Creek during this period are virtually identical to those of the summer survey, though the magnitude of the species enrichment is somewhat different due to differing amounts of ground water runoff and industrial activity. This is especially true for the dissolved solids burden, which during the fall survey was twice as high in Brush Creek from station B2 through station B8 as compared with natural background levels. It should be noted that for this comparison the stream stations B1 and S1 cannot be considered adquate controls for lower Brush Creek stations,since there was no flow at these two stations during the fall sampling period. Spring Creek station 2 however, functions as a satisfactory control for comparison of the fall survey data.

Average values for industrial outfall constituents in October were likewise similar to levels observed during summer sampling. Industrial station 1 was the major contributor to general water quality alteration in the Brush Creek system. Industrial outfalls 2, 4 and 5 were found to be sources of nitrate-nitrogen and total phosphorus. The effluent from industrial station 3 was again observed to contain appreciable quantities of nitrate-nitrogen, total phosphorus and chromium. The discharge from industrial station 7 was significantly cleaner with respect to the general water quality parameters during the fall sampling than it was during the summer survey.

Water samples taken during the fall survey were not analyzed for the trace metals cadmium, iron, manganese and mercury. The analyses were precluded since the concentrations of these components in the summer samplings were not especially high and could not be considered environ-

mentally significant effects of IAAP industrial operations on the Brush Creek stream system.

The range of daily variation in general water quality at each of the stream and industrial stations is presented in Tables 8 through 23. The mean value of the five daily samples for each survey is listed, along with the maximum and minimum values observed during that survey period. For ease of comparison, the information of both summer and fall surveys are presented on the same table.

In general, there is considerable daily variation in water quality at Brush Creek stations B2 through B8 during both survey periods. This variation is primarily evident in the major solutes and in the nutrient species. Though considerable variation of these components is observed in the daily discharges from industrial outfalls 2, 3, 4, 5 and 7, it is quite likely that most of the daily variation seen in Brush Creek is the result of the variable nature of the effluent at industrial station 1. During the summer survey, discharges at this outfall were extremely variable in chemical content as well as temperature, and slugs of concentrated boiler blowdown water doubtless had an effect on the ecology of Brush Creek.

Results from the diurnal study performed during the summer survey are presented in Table 24. Though some variation in the general water quality can be inferred from the pH and specific conductance data, this variation is within that seen in samples gathered from stream and industrial stations during the periods of production line operation. It is noteworthy here that since no low levels of dissolved oxygen were observed in any of the industrial or stream samples taken during the periods of plant operation, it was deemed unnecessary to monitor D.O. during the diurnal study.

Table 8 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B1

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 (a) Value
Specific Conductance	μmhos/cm	520	540	508	1500
Total Solids	mg/l	355	418	312	1480
Total Suspended Solids	mg/l	31	40	25	40
pH	SU	8.25*	8.40	8.10	6.60*
Total Alkalinity	mg/l as $CaCO_3$	184	188	180	146
Chloride	mg/l	37.1	41.6	27.8	25.7
Sulfate	mg/l	38	45	35	870
Total Hardness	mg/l as $CaCO_3$	280	285	278	890
Calcium	mg/l	65.9	66.5	65.5	200
Magnesium	mg/l	28.2	28.9	27.8	95
Sodium	mg/l	12	12	12	34
Potassium	mg/l	0.5	0.6	0.4	3.4
Dissolved Oxygen	mg/l	8.5	9.2	7.4	6.2
BOD	mg/l	2	2	1	2
COD	mg/l	8 (3/5)	14	<5	14
TOC	mg/l	4	9	2	6
Kjeldahl-N	mg/l	0.8	2.6	0.3	0.8
Ammonia-N	mg/l	0.084	0.12	0.047	0.44
Nitrite-N	mg/l	0.028	0.033	0.023	0.003
Nitrate-N	mg/l	3.6	4.3	3.1	0.092

Table 8 . Continued

Parameter	Units	Mean	June 1975 Max.	Min.	October 1975 (a) Value
Total Phosphorus	mg/l	0.073	0.13	0.027	0.030
Cadmium	mg/l		<0.0005		-
Chromium	mg/l	0.005	0.005	0.004	0.001
Iron	mg/l	1.13	1.40	0.88	-
Lead	mg/l	0.003	0.004	0.002	0.008
Manganese	mg/l	0.154	0.170	0.135	-
Mercury	mg/l	0.0001	0.0001	0.0001	-

* *Median Value*

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 9. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B2

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	740	1120	590	1040	2620	480
Total Solids	mg/l	476	781	370	789	1970	433
Total Suspended Solids	mg/l	13	42	2	17	64	2
pH	SU	9.30*	9.15	9.25	9.35*	9.65	8.80
Total Alkalinity	mg/l as $CaCO_3$	153	156	148	153	187	127
Chloride	mg/l	109	274	58.7	241	793	70.5
Sulfate	mg/l	73	86	63	98	110	67
Total Hardness	mg/l as $CaCO_3$	159	166	153	229	611	128
Calcium	mg/l	33.7	35.7	32.3	45.1	118	25.6
Magnesium	mg/l	18.2	18.9	17.3	28.2	77	15.5
Sodium	mg/l	80	94	72	172	426	67
Potassium	mg/l	2.5	3.4	2.0	10.6	16.5	7.9
Dissolved Oxygen	mg/l	8.4	9.2	7.8	8.4	8.8	8.0
BOD	mg/l	2	4	1	3	3	2
COD	mg/l	14	17	10	18	21	15
TOC	mg/l	15	22	9	7	9	3
Kjeldahl-N	mg/l	0.7	0.9	0.5	0.9	1.4	0.6
Ammonia-N	mg/l	0.083	0.16	0.051	0.24	0.68	0.079
Nitrite-N	mg/l	0.009	0.011	0.007	0.005	0.009	0.002
Nitrate-N	mg/l	4.1	4.6	3.1	0.40	0.68	0.20

Table 9. Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.58	0.71	0.32	0.71	0.89	0.49
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.163	0.296	0.021	0.108	0.105	0.032
Iron	mg/l	0.58	1.33	0.33	-	-	-
Lead	mg/l	0.003	0.004	0.002	0.002	0.003	0.001
Manganese	mg/l	0.115	0.120	0.100	-	-	-
Mercury	mg/l	0.0002	0.0002	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 10. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B3

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
Specific Conductance	μmhos/cm	720	1100	560	1100	2480	740
Total Solids	mg/l	467	694	350	776	1710	515
Total Suspended Solids	mg/l	14	30	6	5	10	2
pH	SU	9.30*	9.45	9.20	9.25*	9.50	9.10
Total Alkalinity	mg/l as $CaCO_3$	153	157	149	159	188	138
Chloride	mg/l	97.3	210	61.9	234	647	117
Sulfate	mg/l	71	76	69	100	110	90
Total Hardness	mg/l as $CaCO_3$	164	169	156	213	518	132
Calcium	mg/l	35.0	36.5	33.5	40.7	95.6	26.5
Magnesium	mg/l	18.6	19.3	17.6	27.2	68	15.9
Sodium	mg/l	99	172	73	176	366	122
Potassium	mg/l	2.8	3.3	2.3	10.2	15.8	8.2
Dissolved Oxygen	mg/l	8.2	9.0	7.4	8.5	9.0	8.1
BOD	mg/l	1	3	1	2	3	2
COD	mg/l	14	23	7	19	27	13
TOC	mg/l	25	60	7	8	8	7
Kjeldahl-N	mg/l	0.7	0.9	0.5	0.8	1.1	0.6
Ammonia-N	mg/l	0.11	0.15	0.091	0.28	0.73	0.029
Nitrite-N	mg/l	0.010	0.013	0.006	0.007	0.010	0.004
Nitrate-N	mg/l	3.7	4.0	3.3	0.30	0.38	0.22

Table 10 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.56	0.72	0.12	0.77	0.93	0.45
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.122	0.266	0.031	0.058	0.130	0.036
Iron	mg/l	0.65	1.20	0.44	-	-	-
Lead	mg/l	0.003	0.004	0.002	0.001 (4/5)	0.001	0.001
Manganese	mg/l	0.111	0.140	0.090	-	-	-
Mercury	mg/l	0.0001	0.0002	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 11. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B4

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
Specific Conductance	µmhos/cm	630	700	590	1060	1700	820
Total Solids	mg/1	412	457	388	724	1090	584
Total Suspended Solids	mg/1	8	12	5	2	4	1
pH	SU	9.30*	9.40	8.55	9.35*	9.50	9.15
Total Alkalinity	mg/1 as $CaCO_3$	152	155	148	162	198	147
Chloride	mg/1	72.8	79.7	63.7	258	504	133
Sulfate	mg/1	71	77	65	100	110	91
Total Hardness	mg/1 as $CaCO_3$	151	158	143	204	362	140
Calcium	mg/1	34.1	35.7	32.6	38.2	64.4	28.4
Magnesium	mg/1	16.1	16.7	14.9	26.4	49	16.8
Sodium	mg/1	84	90	75	170	239	138
Potassium	mg/1	3.2	3.6	2.9	10.6	13.4	9.1
Dissolved Oxygen	mg/1	8.6	10.0	7.6	9.4	9.9	8.7
BOD	mg/1	2	3	1	2	3	2
COD	mg/1	23	45	12	20	24	16
TOC	mg/1	16	34	9	6	9	3
Kjeldahl-N	mg/1	0.8	0.9	0.6	0.8	0.9	0.7
Ammonia-N	mg/1	0.12	0.13	0.099	0.22	0.62	0.031
Nitrite-N	mg/1	0.016	0.029	0.010	0.005	0.008	0.004
Nitrate-N	mg/1	3.2	3.5	2.5	0.21	0.30	0.13

Table 11. Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.52	0.66	0.15	0.75	0.90	0.45
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.095	0.175	0.024	0.034	0.041	0.025
Iron	mg/l	0.41	0.48	0.35	-	-	-
Lead	mg/l	0.002	0.002	0.002	0.001 (4/5)	0.001	< 0.001
Manganese	mg/l	0.063	0.075	0.050	-	-	-
Mercury	mg/l	0.0001	0.0001	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 12 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B5

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	550	580	510	1200	1770	800
Total Solids	mg/1	382	419	316	854	1250	509
Total Suspended Solids	mg/1	17	30	10	7	10	4
pH	SU	9.10*	9.40	9.10	8.60*	9.00	8.60
Total Alkalinity	mg/1 as $CaCO_3$	131	140	119	153	185	139
Chloride	mg/1	58.6	63.9	54.2	353	631	130
Sulfate	mg/1	61	65	57	96	104	89
Total Hardness	mg/1 as $CaCO_3$	149	158	138	236	350	141
Calcium	mg/1	33.9	36.2	30.9	42.0	57.7	24.7
Magnesium	mg/1	15.7	16.6	14.7	31.9	50	19.4
Sodium	mg/1	61	66	58	187	286	103
Potassium	mg/1	3.1	3.4	2.8	11.5	14.0	9.0
Dissolved Oxygen	mg/1	8.4	9.0	7.6	9.4	10.1	9.0
BOD	mg/1	4	8	2	2	3	2
COD	mg/1	18	41	9	17	25	13
TOC	mg/1	10	11	5	7	9	6
Kjeldahl-N	mg/1	2.0	5.0	0.6	0.7	0.9	0.6
Ammonia-N	mg/1	1.5	5.1	0.067	0.15	0.28	0.045
Nitrite-N	mg/1	0.11	0.26	0.008	0.008	0.013	0.004
Nitrate-N	mg/1	4.3	7.4	2.1	0.45	1.0	0.14

AD-A036 776 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITI--ETC(U)
NOV 76 S L SANOCKI, P B SIMON, R L WEITZEL DAMD17-75-C-5046

UNCLASSIFIED NL

2 OF 5
AD
A036776

2 OF 5

36776

1.0 4.5 2.8 2.5

5.0 3.2 2.2

5.6 3.6

6.3 4.0 2.0

7.1

1.1

1.8

1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

Table 12 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.47	0.79	0.18	1.6	2.4	0.97
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.044	0.085	0.015	0.029	0.038	0.014
Iron	mg/l	0.91	1.70	0.41	-	-	-
Lead	mg/l	0.003	0.003	0.002	0.001 (4/5)	0.001	0.001
Manganese	mg/l	0.135	0.190	0.070	-	-	-
Mercury	mg/l	0.0001	0.0001	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 13. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B6

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	870	1420	600	950	1520	720
Total Solids	mg/l	566	934	379	711	942	570
Total Suspended Solids	mg/l	4	8	1	7	12	4
pH	SU	8.80*	9.10	8.50	8.40*	8.80	8.30
Total Alkalinity	mg/l as $CaCO_3$	141	149	132	160	171	151
Chloride	mg/l	162	337	75.0	209	392	110
Sulfate	mg/l	61	66	55	96	104	92
Total Hardness	mg/l as $CaCO_3$	194	290	149	206	335	155
Calcium	mg/l	42.0	61.0	34.0	38.6	65.2	26.4
Magnesium	mg/l	21.8	33.4	15.6	26.7	42	19.3
Sodium	mg/l	105	183	68	142	184	115
Potassium	mg/l	4.2	5.9	3.2	10.6	13.0	7.9
Dissolved Oxygen	mg/l	8.5	9.2	7.7	10.3	10.8	10.0
BOD	mg/l	2	3	1	3	4	3
COD	mg/l	10	14	7	21	30	16
TOC	mg/l	12	31	6	6	9	3
Kjeldahl-N	mg/l	0.6	0.8	0.5	0.7	0.9	0.6
Ammonia-N	mg/l	0.11	0.14	0.082	0.043	0.10	0.024
Nitrite-N	mg/l	0.010	0.020	0.004	0.007	0.012	0.001
Nitrate-N	mg/l	2.4	2.8	2.0	1.1	5.1	0.067

Table 13 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.59	0.70	0.47	3.7	8.7	1.4
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.042	0.085	0.008	0.058	0.088	0.011
Iron	mg/l	0.32	0.94	0.14	-	-	-
Lead	mg/l	0.002	0.003	0.002		<0.001	
Manganese	mg/l	0.035	0.070	0.020	-	-	-
Mercury	mg/l	0.0001	0.0001	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 14 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B7

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
Specific Conductance	μmhos/cm	670	930	510	640	980	510
Total Solids	mg/l	428	574	334	469	599	356
Total Suspended Solids	mg/l	7	10	2	46	209	4
pH	SU	8.60*	8.75	8.20	8.20*	8.40	8.20
Total Alkalinity	mg/l as $CaCO_3$	133	151	127	135	141	130
Chloride	mg/l	110	201	57.5	109	194	76.6
Sulfate	mg/l	61	70	56	67	71	61
Total Hardness	mg/l as $CaCO_3$	181	243	151	185	241	166
Calcium	mg/l	38.8	53.0	31.5	37.4	47.6	31.2
Magnesium	mg/l	20.6	27.0	17.1	22.4	27.8	19.7
Sodium	mg/l	70	103	48	75	100	60
Potassium	mg/l	4.8	5.7	4.4	7.6	8.9	6.7
Dissolved Oxygen	mg/l	9.2	9.9	8.4	9.4	9.9	9.2
BOD	mg/l	4	5	2	2	3	2
COD	mg/l	15	21	12	11	20	6
TOC	mg/l	9	16	6	6	10	2
Kjeldahl-N	mg/l	0.9	1.4	0.7	0.9	1.3	0.7
Ammonia-N	mg/l	0.42	1.4	0.093	0.086	0.12	0.068
Nitrite-N	mg/l	0.008	0.012	0.005	0.004	0.009	0.001
Nitrate-N	mg/l	4.6	5.9	2.4	3.1	5.6	1.4

Table 14. Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.94	1.2	0.54	2.2	4.6	1.3
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.042	0.104	0.012	0.026	0.036	0.006
Iron	mg/l	0.48	0.70	0.28	-	-	-
Lead	mg/l	0.003	0.004	0.003		<0.001	
Manganese	mg/l	0.086	0.115	0.045	-	-	-
Mercury	mg/l	0.0007	0.0013	0.0004	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 15 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
BRUSH CREEK STATION B8

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	570	600	530	700	820	640
Total Solids	mg/l	365	387	350	486	545	439
Total Suspended Solids	mg/l	3	5	2	3	5	1
pH	SU	8.90*	9.00	8.65	8.10*	8.20	8.05
Total Alkalinity	mg/l as $CaCO_3$	145	148	139	155	166	148
Chloride	mg/l	68.8	82.2	63.4	136	154	121
Sulfate	mg/l	60	64	56	77	84	68
Total Hardness	mg/l as $CaCO_3$	185	192	173	223	232	211
Calcium	mg/l	42.9	45.0	39.6	47.2	50.0	45.0
Magnesium	mg/l	19.1	19.9	18.1	25.7	26.4	24.1
Sodium	mg/l	45	50	41	86	96	79
Potassium	mg/l	4.0	4.2	3.8	8.8	9.2	8.2
Dissolved Oxygen	mg/l	10.2	11.1	8.7	9.4	9.8	8.9
BOD	mg/l	2	3	1	2	2	2
COD	mg/l	10	14	6	14	16	11
TOC	mg/l	6	11	3	5	8	3
Kjeldahl-N	mg/l	0.5	0.6	0.4	0.7	0.7	0.6
Ammonia	mg/l	0.075	0.12	0.051	0.032	0.043	0.028
Nitrite-N	mg/l	0.005	0.007	0.003	0.007	0.009	0.003
Nitrate-N	mg/l	4.1	5.2	2.7	1.5	2.3	0.36

Table 15. Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.72	0.85	0.59	1.6	2.0	1.2
Cadmium	mg/l		<0.0005		-	-	-
Chromium	mg/l	0.013	0.024	0.006	0.017	0.024	0.003
Iron	mg/l	0.25	0.35	0.20	-	-	-
Lead	mg/l	0.002	0.002	0.001		<0.001	
Manganese	mg/l	0.028	0.045	0.010	-	-	-
Mercury	mg/l	0.0001	0.0002	0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 16 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
SPRING CREEK STATION S1

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	520	550	510	690	880	610
Total Solids	mg/l	321	363	259	529	624	442
Total Suspended Solids	mg/l	8	14	4	30	50	16
pH	SU	8.50*	8.75	8.20	7.80*	7.95	7.75
Total Alkalinity	mg/l as $CaCO_3$	193	208	182	264	337	168
Chloride	mg/l	45.5	55.9	39.2	90.8	105	87.8
Sulfate	mg/l	37	43	34	49	80	30
Total Hardness	mg/l as $CaCO_3$	260	271	248	365	412	313
Calcium	mg/l	61.7	64.5	58.5	81.5	95.9	63.7
Magnesium	mg/l	25.7	26.8	24.7	39.4	42.0	37.5
Sodium	mg/l	24	29	22	36	39	34
Potassium	mg/l	1.5	1.7	1.3	9.2	9.9	8.1
Dissolved Oxygen	mg/l	9.0	9.4	8.1	6.1	7.1	5.0
BOD	mg/l	2	3	2	11	>13	7
COD	mg/l	10 (1/5)	13	<5	40	54	31
TOC	mg/l	5	6	3	9	16	3
Kjeldahl-N	mg/l	0.5	0.6	0.4	0.9	1.2	0.8
Ammonia-N	mg/l	0.069	0.10	0.040	0.053	0.12	0.017
Nitrite-N	mg/l	0.034	0.053	0.020	0.006	0.010	0.001
Nitrate-N	mg/l	1.1	1.7	0.21	0.076	0.14	0.009

Table 16 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/l	0.13	0.18	0.020	0.40	0.84	0.23
Cadmium	mg/l	0.0003	0.0004	0.0002	-	-	-
Chromium	mg/l	0.005	0.008	0.004	0.001	0.002	0.001
Iron	mg/l	0.32	0.38	0.20	-	-	-
Lead	mg/l		<0.001			<0.001	
Manganese	mg/l	0.111	0.161	0.062	-	-	-
Mercury	mg/l		<0.0001		-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 17 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
SPRING CREEK STATION S2

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
Specific Conductance	μmhos/cm	510	560	480	530	650	480
Total Solids	mg/1	334	376	278	373	407	349
Total Suspended Solids	mg/1	31	73	15	5	9	2
pH	SU	8.40*	8.50	8.20	7.80*	7.90	7.70
Total Alkalinity	mg/1 as $CaCO_3$	198	203	196	252	257	248
Chloride	mg/1	35.3	37.6	33.5	40.9	48.3	37.2
Sulfate	mg/1	38	42	33	57	94	45
Total Hardness	mg/1 as $CaCO_3$	258	264	251	298	310	266
Calcium	mg/1	62.7	64.2	60.5	70.2	75.0	58.2
Magnesium	mg/1	24.7	25.2	24.3	29.9	30.9	29.5
Sodium	mg/1	21	23	19	35	36	34
Potassium	mg/1	2.2	2.4	2.1	5.2	5.6	4.7
Dissolved Oxygen	mg/1	9.7	10.1	9.4	8.0	9.0	6.9
BOD	mg/1	2	3	2	3	3	3
COD	mg/1	12	17	7	12	16	6
TOC	mg/1	6	8	4	6	6	5
Kjeldahl-N	mg/1	0.6	0.7	0.5	0.5	0.5	0.4
Ammonia-N	mg/1	0.11	0.14	0.082	0.067	0.094	0.046
Nitrite-N	mg/1	0.012	0.029	0.008	0.006	0.009	0.004
Nitrate-N	mg/1	0.73	1.2	0.50	0.063	0.10	0.009

Table 17 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Total Phosphorus	mg/1	0.13	0.19	0.028	0.15	0.19	0.12
Cadium	mg/1	0.0002	0.0002	0.0001	-	-	-
Chromium	mg/1	0.010	0.012	0.008	0.001	0.002	0.001
Iron	mg/1	0.53	0.94	0.34	-	-	-
Lead	mg/1	0.003	0.006	0.001	0.001 (4/5)	0.001	< 0.001
Manganese	mg/1	0.149	0.187	0.125	-	-	-
Mercury	mg/1		<0.0001		-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 18. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 1

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	µmhos/cm	8290	34200	1720	2180	3100	1020
Total Solids	mg/l	6380	27500	991	1200	1480	675
Total Suspended Solids	mg/l	130	261	80	172	400	82
pH	SU	10.95*	11.30	9.80	10.85*	11.50	10.45
Total Alkalinity	mg/l as $CaCO_3$	327	440	196	411	525	228
Chloride	mg/l	2620	12500	123	337	603	188
Sulfate	mg/l	215	276	177	240	300	150
Total Hardness	mg/l as $CaCO_3$	780	3800	15	35	84	12
Calcium	mg/l	25.9	107	3.5	9.2	15.7	3.2
Magnesium	mg/l	170	860	1.0	2.8	10.9	0.5
Sodium	mg/l	1560	6250	325	369	478	186
Potassium	mg/l	37.0	165	4.4	18.4	40.6	10.4
Dissolved Oxygen	mg/l	7.0	7.7	6.3	7.0	7.6	6.4
BOD	mg/l	15	25	6	20	30	10
COD	mg/l	57	93	6	74	111	46
TOC	mg/l	24	33	14	16	18	14
Kjeldahl-N	mg/l	1.2	1.6	0.7	1.3	2.3	0.7
Ammonia-N	mg/l	0.075	0.12	0.049	0.062	0.13	0.040
Nitrite-N	mg/l	0.009	0.012	0.007	0.001(1/5)	0.003	<0.001

Table 18. Continued

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
Nitrate-N	mg/l	14	31	6.2	0.67	0.85	0.30
Total Phosphorus	mg/l	5.4	9.9	1.2	8.2	13	4.4
Cadmium	mg/l	0.0024	0.0083	0.0007	-	-	-
Chromium	mg/l	0.010	0.026	0.005	0.075	0.134	0.043
Iron	mg/l	0.38	0.58	0.19	-	-	-
Lead	mg/l	0.017	0.073	0.003	0.007	0.018	0.003
Manganese	mg/l	0.055	0.026	0.087	-	-	-
Mercury	mg/l	(2/5) 0.0006	0.0026	<0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 19 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 2

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	440	650	380	362	390	330
Total Solids	mg/l	299	448	246	224	259	190
Total Suspended Solids	mg/l	9	16	2	8	17	2
pH	SU	7.75*	7.85	7.40	7.90*	8.15	7.90
Total Alkalinity	mg/l as $CaCO_3$	118	135	108	114	120	111
Chloride	mg/l	37.5	55.0	29.6	43.5	53.1	34.0
Sulfate	mg/l	51	83	42	45	48	43
Total Hardness	mg/l as $CaCO_3$	180	217	168	160	172	145
Calcium	mg/l	38.7	44.1	36.0	32.9	36.8	27.7
Magnesium	mg/l	20.6	26.0	18.0	19.0	20.2	18.4
Sodium	mg/l	29	55	20	37	39	36
Potassium	mg/l	2.5	3.6	2.0	4.4	5.4	4.0
Dissolved Oxygen	mg/l	7.5	8.4	6.2	8.9	9.4	8.7
BOD	mg/l	2	3	1	1 (2/5)	1	<1
COD	mg/l	13	25	6	8 (2/5)	14	<5
TOC	mg/l	8	10	4	4	6	2
Kjeldahl-N	mg/l	0.7	1.1	0.4	0.4	0.5	0.3
Ammonia-N	mg/l	0.076	0.13	0.059	0.050	0.068	0.021
Nitrite-N	mg/l	0.005	0.008	0.003	0.003	0.006	0.001

Table 19. Continued

Parameters	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Nitrate-N	mg/1	2.7	5.5	1.3	0.11	0.22	0.068
Total Phosphorus	mg/1	0.16	0.25	0.079	0.11	0.18	0.088
Cadmium	mg/1	0.0001	0.0001	0.0001	-	-	-
Chromium	mg/1	(1/5) 0.003	0.005	<0.002	0.003	0.006	0.001
Iron	mg/1	0.32	0.56	0.15	-	-	-
Lead	mg/1	(2/5) 0.005	0.019	<0.001	(3/5) 0.001	0.001	<0.001
Manganese	mg/1	0.160	0.192	0.145	-	-	-
Mercury	mg/1	(2/5) 0.0002	0.0004	<0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 20. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION 1 3

Parameter	Units		June 1975 Mean	June 1975 Max.	June 1975 Min.		October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm		411	440	400		388	420	370
Total Solids	mg/1		275	297	252		271	318	200
Total Suspended Solids	mg/1		4	8	1	(1/5)	2	3	<1
pH	SU		7.95*	8.00	7.70		7.80*	8.05	7.65
Total Alkalinity	mg/1 as $CaCO_3$		126	153	112		115	134	106
Chloride	mg/1		27.5	31.6	22.8		59.6	73.1	54.5
Sulfate	mg/1		45	51	33		60	66	55
Total Hardness	mg/1 as $CaCO_3$		181	202	171		170	187	158
Calcium	mg/1		39.7	47.2	36.3		32.1	34.9	29.8
Magnesium	mg/1		20.0	20.6	19.6		21.8	24.2	20.3
Sodium	mg/1		24	29	19		39	40	37
Potassium	mg/1		2.7	3.3	2.4		8.5	10.8	7.3
Dissolved Oxygen	mg/1		7.6	8.4	7.1		8.1	8.4	7.9
BOD	mg/1		2	4	1		3	4	2
COD	mg/1	(1/3)	7	10	<5		12	14	9
TOC	mg/1		15	30	4		6	9	3
Kjeldahl-N	mg/1		0.6	0.6	0.5		1.1	1.6	0.6
Ammonia-N	mg/1		0.080	0.11	0.051		0.60	1.0	0.062
Nitrite-N	mg/1	(1/5)	0.003	0.005	<0.001		0.017	0.042	0.003

Table 20. Continued

Parameter	Units		June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Nitrate-N	mg/1		2.0	3.1	0.30	0.49	0.73	0.24
Total Phosphorus	mg/1		0.074	0.20	0.027	0.71	1.4	0.28
Cadmium	mg/1		0.0002	0.0005	0.0001	-	-	-
Chromium	mg/1		0.420	0.650	0.178	0.397	0.600	0.099
Iron	mg/1		0.16	0.22	0.10	-	-	-
Lead	mg/1		0.001	0.001	0.001	0.002	0.004	0.001
Manganese	mg/1		0.072	0.110	0.049	-	-	-
Mercury	mg/1	(4/5)	0.0001	0.0002	<0.0001	-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 21 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 4

Parameter	Units		June 1975 Mean	June 1975 Max.	June 1975 Min.		October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm		303	320	260		292	330	270
Total Solids	mg/l		179	212	126		197	235	155
Total Suspended Solids	mg/l	(1/5)	3	4	<1	(1/5)	6	22	<1
pH	SU		8.30*	8.40	8.15		7.90*	8.05	7.90
Total Alkalinity	mg/l as $CaCO_3$		124	139	110		100	102	97
Chloride	mg/l		16.2	19.2	12.6		36.9	44.5	31.4
Sulfate	mg/l		21	24	18		36	47	30
Total Hardness	mg/l as $CaCO_3$		154	168	133		136	153	127
Calcium	mg/l		38.4	42.2	35.1		29.6	33.6	27.1
Magnesium	mg/l		14.4	15.6	12.5		15.0	16.8	14.2
Sodium	mg/l		12	14	11		32	34	31
Potassium	mg/l		1.1	1.3	1.0		5.0	9.4	3.0
Dissolved Oxygen	mg/l		8.3	9.1	7.8		8.9	9.7	8.6
BOD	mg/l		1	2	1	(1/5)	1	2	<1
COD	mg/l		39	92	6	(1/5)	12	35	<5
TOC	mg/l		5	6	3		4	7	1
Kjeldahl-N	mg/l		0.4	0.5	0.3		0.5	0.9	0.3
Ammonia-N	mg/l		0.075	0.096	0.048		0.068	0.096	0.029
Nitrite-N	mg/l		0.004	0.007	0.001		0.005	0.012	0.002

Table 21. Continued

Parameter	Units		June 1975 Mean	June 1975 Max.	June 1975 Min.		October 1975 Mean	October 1975 Max.	October 1975 Min.
Nitrate-N	mg/l		2.5	9.7	0.50		0.38	0.68	0.23
Total Phosphorus	mg/l		0.091	0.18	0.002		1.1	1.3	0.87
Cadmium	mg/l		0.0001	0.0001	0.0001		-	-	-
Chromium	mg/l		0.052	0.116	0.008		0.005	0.011	0.003
Iron	mg/l		0.20	0.22	0.17		-	-	-
Lead	mg/l	(4/5)	0.001	0.001	<0.001	(4/5)	0.001	0.001	<0.001
Manganese	mg/l		0.120	0.145	0.099		-	-	-
Mercury	mg/l			<0.0001			-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 22. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 5

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.		October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	348	370	335		376	430	342
Total Solids	mg/l	238	274	216		321	449	258
Total Suspended Solids	mg/l	15	42	6		10	14	4
pH	SU	7.65*	7.80	7.40		6.70*	7.40	6.45
Total Alkalinity	mg/l as $CaCO_3$	91	99	87		72	100	56
Chloride	mg/l	30.1	32.2	28.6		39.6	43.1	36.1
Sulfate	mg/l	39	47	24		52	56	49
Total Hardness	mg/l as $CaCO_3$	145	150	142		145	151	137
Calcium	mg/l	28.8	30.6	27.8		26.5	28.8	24.7
Magnesium	mg/l	17.8	18.1	17.6		19.3	19.9	19.3
Sodium	mg/l	23	24	22		48	58	39
Potassium	mg/l	2.5	2.6	2.4		4.7	5.2	4.1
Dissolved Oxygen	mg/l	7.6	8.2	6.5		8.3	8.6	8.1
BOD	mg/l	2	3	1	(3/5)	1	1	<1
COD	mg/l	16	26	7	(2/5)	9	14	<5
TOC	mg/l	7	11	4		6	8	3
Kjeldahl-N	mg/l	0.8	1.0	0.6		0.6	0.7	0.5
Ammonia-N	mg/l	0.083	0.13	0.050		0.18	0.29	0.12
Nitrite-N	mg/l	0.005	0.008	0.002		0.003	0.005	0.002

Table 22. Continued

Parameter	Units		June 1975 Mean	Max.	Min.	October 1975 Mean	Max.	Min.
Nitrate-N	mg/l		2.5	2.8	2.3	5.2	9.0	1.1
Total Phosphorus	mg/l		0.82	1.3	0.50	32	56	8.8
Cadmium	mg/l		0.0001	0.0003	0.0001	-	-	-
Chromium	mg/l	(4/5)	0.003	0.005	<0.002	0.618	1.05	0.034
Iron	mg/l		0.34	0.84	0.15	-	-	-
Lead	mg/l	(4/5)	0.001	0.001	<0.001		<0.001	
Manganese	mg/l		0.059	0.095	0.042	-	-	-
Mercury	mg/l			<0.0001		-	-	-

*Median Value

(a) only one sample obtained during fall survey

Note: "less than" value for Max. indicates material not detected at the indicated level of detection.

Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 23. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 7

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Specific Conductance	μmhos/cm	352	410	258	358	380	330
Total Solids	mg/l	225	306	173	230	246	211
Total Suspended Solids	mg/l	11	24	4	5	10	3
pH	SU	7.75*	8.15	7.60	7.95*	8.05	7.90
Total Alkalinity	mg/l as $CaCO_3$	98	110	82	115	124	102
Chloride	mg/l	30.9	34.6	27.3	42.9	45.5	39.4
Sulfate	mg/l	38	45	19	51	66	44
Total Hardness	mg/l as $CaCO_3$	160	168	149	166	175	159
Calcium	mg/l	34.4	36.2	32.6	33.4	37.0	29.9
Magnesium	mg/l	18.0	18.9	16.4	20.1	20.6	19.6
Sodium	mg/l	22	22	21	35	35	35
Potassium	mg/l	2.5	2.7	2.1	4.0	4.1	4.0
Dissolved Oxygen	mg/l	7.5	8.6	6.6	8.6	9.0	8.2
BOD	mg/l	5	9	2	1	2	1
COD	mg/l	(1/5) 32	81	<5	(3/5) 6	9	<5
TOC	mg/l	5	12	2	4	5	3
Kjeldahl-N	mg/l	5.1	14.2	0.4	0.4	0.4	0.3
Ammonia-N	mg/l	4.1	12	0.083	0.083	0.14	0.039
Nitrite-N	mg/l	0.15	0.34	0.003	0.057	0.089	0.023

Table 23 . Continued

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
Nitrate-N	mg/1	8.0	19	2.6	0.56	0.87	0.36
Total Phosphorus	mg/1	0.048	0.094	0.015	0.042	0.085	0.018
Cadmium	mg/1	0.0003	0.0005	0.0001	-	-	-
Chromium	mg/1	0.005	0.013	0.002	0.002	0.003	0.001
Iron	mg/1	0.43	0.79	0.26	-	-	-
Lead	mg/1	0.001	0.002	0.001		<0.001	
Manganese	mg/1	0.170	0.210	0.149	-	-	-
Mercury	mg/1		<0.0001		-	-	-

*Median Value

(a) only one sample obtained during fall survey
Note: "less than" value for Max. indicates material not detected at the indicated level of detection.
Note: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).
Note: dashes indicate analysis not performed due to apparent insignificance of parameter in spring survey.

Table 24 . IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA-DIURNAL STUDY
BRUSH CREEK
23-25 JUNE 1975

		Station B1		Station B8	
Date	Time	Specific Conductance µmhos/cm	pH SU	Specific Conductance µmhos/cm	pH SU
23 June 1975	7:00 PM	325	8.35	-	-
	8:00	405	8.35	418	8.63
	9:00	380	8.30	492	8.50
	10:00	338	8.25	488	8.32
	11:00	415	8.25	470	8.18
	12:00	453	8.25	600	8.19
24 June 1975	1:00 AM	355	8.27	600	8.15
	2:00	455	8.30	690	8.10
	3:00	318	8.28	720	8.10
	4:00	480	8.25	690	8.10
	5:00	-	-	590	8.06
	6:00	-	-	520	8.05
	7:00	-	-	505	8.12
	8:00	-	-	610	8.23
	9:00	-	-	600	8.43
	10:00	-	-	370	8.75
	11:00	329	8.10	338	8.75
	12:00	-	-	320	8.90
	1:00 PM	380	8.15	390	8.92
	2:00	360	8.43	420	8.97
	3:00	361	8.35	419	8.93
	4:00	361	8.37	380	8.95
	5:00	305	8.32	380	8.90
	6:00	360	8.25	382	8.77
	7:00	390	7.12	462	8.68
	8:00	330	7.50	432	8.50
	9:00	380	7.72	450	8.28
	10:00	420	7.80	480	8.13
	11:00	390	7.90	463	8.10
	12:00	500	7.98	382	7.90

Table 24 . Continued

		Station B1		Station B8	
Date	Time	Specific Conductance µmhos/cm	pH SU	Specific Conductance µmhos/cm	pH SU
25 June 1975	1:00 AM	600	8.02	350	7.85
	2:00	598	8.02	320	7.87
	3:00	501	8.04	370	7.88
	4:00	499	8.06	380	7.85
	5:00	432	8.06	352	7.88
	6:00	450	8.02	342	7.90
	7:00	452	8.00	408	7.90
	8:00	460	8.00	345	7.92
	9:00	500	8.06	322	7.92
	10:00	200	8.15	282	8.75
	11:00	192	8.30	310	8.50
	12:00	342	8.25	335	8.20
	1:00 PM	376	8.15	246	8.35
	2:00	395	8.30	335	8.30
	3:00	233	8.30	352	8.30
	4:00	321	8.00	397	8.40
	5:00	358	8.15	466	8.40
	6:00	390	8.35	650	8.30
	7:00	375	8.45	650	8.40

Aqueous Phase

Munitions Compounds -

Average values for munitions-related compounds in the aqueous phase are presented in Tables 25 through 30 (individual results of each daily sample can be found in the appendices). The analysis of samples from the IAAP was tailored to provide quantitative information on 2, 6 - dinitrotoluene and 2, 4 - dinitrotoluene (both minor components in technical grade TNT), 1, 3, 5 - trinitrobenzene (an important photolysis product of alpha TNT), 2,4, 6 - trinitrotoluene(the main TNT isomer), and 4 - hydroxylamino- 2, 6 - dinitrotoluene and 2 - hydroxylamino- 4, 6 - dinitrotoluene (two environmental transformation products of alpha TNT). Detection limits for each of the compounds were determined by the minimum amount of each compound which could be distinguished with adequate confidence from the indigenous oils present in each sample extract. For this reason, detection limits vary from compound to compound, from station to station, and occasionally from sample to sample.

During the June sampling period, munitions - related compounds were detected in the aqueous phase at stream stations B2, B4, B5, B6, B7 and B8. No munitions compounds, or their transformation products were found in Spring Creek during this period. Sources of the munitions compounds in Brush Creek are evident from the data on industrial outfall concentrations in Table 27. Industrial stations 4 and 7, and to a lesser extent stations 3 and 5, appear to be the point sources responsible for the munitions - related compounds present in Brush Creek. The levels found at these outfalls are in the low microgram per liter range and probably represent the residual materials remaining in the industrial process water after passage through activated carbon treatment devices.

Samples collected during the fall survey reveal detectable quantities of munitions - related compounds at all Brush Creek stations from B2 through B8, though the average concentrations during this survey period are lower than during June. This probably results from the lower production activity of the IAAP during the fall survey period. Detectable quantities

Table 25. AQUEOUS PHASE MUNITIONS DATA
IOWA ARMY AMMUNITION PLANT JUNE 1975
BRUSH CREEK STATIONS - MEAN

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.2	<0.1	<0.1	<0.2	0.1	<0.1	<0.1	0.1
1,3,5-Trinitrobenzene	μg/l	<0.6	0.2	<0.2	<0.2	0.4	<0.2	0.4	0.7
2,4,6-Trinitoluene	μg/l	<0.2	<0.2	<0.2	2.5	3.4	0.3	4.1	1.3
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	<5	6	<5	6	10	7	8	<5
2,Hydroxylamino-4,6-Dinitrotoluene	μg/l	<10	<10	<10	11	18	12	21	12

Table 26. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
SPRING CREEK STATIONS - MEANS
June 1975

Parameter	Units	Station S1	Station S2
2,6-Dinitrotoluene	µg/l	<0.1	<0.1
2,4-Dinitrotoluene	µg/l	<0.1	<0.1
1,3,5-Trinitrobenzene	µg/l	<0.2	<0.3
2,4,6-Trinitrotoluene	µg/l	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	µg/l	<5	<7
2-Hydroxylamino - 4,6-Dinitrotoluene	µg/l	<24	<18

Table 27. AQUEOUS PHASE MUNITIONS DATA
IOWA ARMY AMMUNITION PLANT JUNE 1975
INDUSTRIAL STATIONS - MEANS

Parameter	Units	Station I1	I2	I3	I4	I5	I7
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	0.2	<0.1	0.2	0.2
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	0.8	<0.2	0.5	0.3
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	0.5	11.7	0.4	3.4
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	<6	<5	6	5	23	7
2-Hydroxylamino-4,6-Dinitrotoluene	μg/l	<10	<10	10	10	32	11

Table 28. AQUEOUS PHASE MUNITIONS DATA
IOWA ARMY AMMUNITION PLANT OCTOBER 1975
BRUSH CREEK STATIONS - MEANS

Parameter	Units	Station B1	B2	B3	B4	B5	B6	B7	B8
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	0.6	0.3	0.5	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	0.5	0.2	0.8	0.5	<0.2	0.5	0.3
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	<5	<5	<5	<5	<5	5	5	<5
2-Hydroxylamino-4,6-Dinitrotoluene	μg/l	<10	<10	<10	<10	<10	<10	<10	<10

Table 29. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
SPRING CREEK STATIONS-MEANS
October 1975

Parameter	Units	Station S1	Station S2
2,6-Dinitrotoluene	μg/l	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.2	<0.1
1,3,5-Trinitrobenzene	μg/l	<3	<0.2
2,4,6-Trinitrotoluene	μg/l	<2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<8	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<70	<10

Table 30 AQUEOUS PHASE MUNITIONS DATA
IOWA ARMY AMMUNITION PLANT OCTOBER 1975
INDUSTRIAL STATIONS - MEANS

Parameter	Units	Det. Limit	Station I1	I2	I3	I4	I5	I7
2,6-Dinitrotoluene	μg/l	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.1	<0.1	<0.1	<0.1	0.2 (4/5)	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	0.2	<0.2	<0.2	<0.2	16.7(1/5)	<0.2	6.0 (1/5)
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	5	<5	<5	7 (0/5)	5 (2/5)	<5	11 (3/5)
2-Hydroxylamino-4,6-Dinitrotoluene	μg/l	10	<10	<10	14 (2/5)	14 (2/5)	<10	20 (3/5)

Note: "less than" value indicates no detectable aount at given detection limit

Note: number in parenthesis represents (number of samples wth concentration below indicated detection limit/total number of samples taken)

of munitions - related compounds were found at industrial stations 3, 4 and 7, with 4 and 7 accounting for the vast majority of the materials. As opposed to the summer samplings, no munitions compounds were found at industrial station 5 during the fall survey. Spring Creek was also free of detectable residues of these compounds during this period.

The range in daily concentrations of munitions - related compounds is presented in Tables 31 through 46. During the June survey, stream stations B4, B5, B7 and B8 and industrial stations 5 and 7 exhibited variations of greater than an order of magnitude in the concentrations of one or more munitions - related compounds. The range of concentrations at station B2 and industrial stations 3 and 4 was somewhat narrower. During the fall survey, daily concentrations varying by more than an order of magnitude were found only in samples from industrial outfalls 4 and 7. Less variance was observed in daily concentrations of munitions - related compounds at Brush Creek stations B2 through B8 and industrial outfalls 3 and 5.

A cautionary statement concerning the evaluation of munitions compounds in the aqueous phase is worthy of mention here. As noted by many researchers, the reactivity of TNT and its related compounds is particularly high in aqueous solutions[1,14,15,19,9,20,21,22]. This is particularly true where chemical transformation can be photochemically or biochemically mediated. Reaction kinetics for these transformations are dependent on many variables, however the reactions often proceed at very rapid rates[14,20, 21]. Therefore, munitions compounds such as DNT and TNT in the aquatic environment may not be present in steady state concentrations. Attempts to develop mass balances for these compounds will be fraught with problems unless all major transformation products are considered in the calculations. At a recent symposium entitled "Symposium on Munitions Standards Research", and sponsored by the U. S. Army Medical Research and Development Command, seventeen different photolysis products of 2, 4, 6 - TNT were identified. More than half a dozen biochemical transformation products have been identified through

Table 31. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B1

		June 1975			October 1975		
Parameter	Units	Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.2	<0.4	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.6	<2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6,-Dinitrotoluene	μg/l	<5	<5	<5	<5	<5	<5
2-Hydroxylamino- 4,6-Dinitrotoluene	μg/l	<10	<10	<10	<10	<10	<10

Table 32. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B2

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	0.1	0.3	<0.1
1,3,5-Trinitrobenzene	μg/l	0.2	0.3	<0.2	0.6	2.0	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	0.5	1.4	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	6	8	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<10	<10	<10	<10	<10	<10

Table 33. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B3

		June 1975			October 1975		
Parameter	Units	Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	0.1	0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	<0.2	0.3	0.5	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	0.2	0.3	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<5	<5	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<10	<10	<10	<10	<10	<10

Table 34. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B4

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	0.1	0.3	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	<0.2	0.5	1.9	<0.2
2,4,6-Trinitrotoluene	μg/l	2.5	8.4	<0.2	0.8	1.8	0.4
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	6	12	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	11	16	<10	<10	<10	<10

Table 35. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B5

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.1	0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.4	0.9	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	3.4	6.7	<0.2	0.5	1.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	10	25	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	18	49	<10	<10	<10	<10

Table 36. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B6

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	µg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	µg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	µg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	µg/l	0.3	0.6	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	µg/l	7	16	<5	5	6	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	µg/l	12	18	<10	<10	<10	<10

Table 37. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B7

		June 1975			October 1975		
Parameter	Units	Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	0.1	0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.4	1.1	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	4.1	15.3	<0.2	0.5	1.9	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	8	11	<5	5	5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	21	40	<10	<10	<10	<10

Table 38. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
BRUSH CREEK STATION B8

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.1	0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.7	2.4	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	1.3	5	<0.2	0.3	0.7	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<5	<5	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	12	18	<10	<10	<10	<10

Table 39. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
SPRING CREEK STATION S1

		June 1975			October 1975		
Parameter	Units	Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.2	<0.3	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	<0.2	<3	<10	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	<2	<10	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<5	<7	<5	<8	<15	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<24	<60	<10	<70	<200	<10

Table 40. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
SPRING CREEK STATION S2

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.3	<0.5	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<7	<15	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<18	<50	<10	<10	<10	<10

Table 41. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION 11

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/1	<6	<7	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/1	<10	<10	<10	<10	<10	<10

Table 42. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION I2

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	<5	<5	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	<10	<10	<10	<10	<10	<10

Table 43. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION I3

Parameter	Units	June 1975 Mean	June 1975 Max.	June 1975 Min.	October 1975 Mean	October 1975 Max.	October 1975 Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.2	0.4	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.8	3.0	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	0.5	1.6	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	6	12	<5	7	9	5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	10	11	<10	14	20	<10

Table 44. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION I4

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	0.2	0.5	<0.1
1,3,5-Trinitrobenzene	μg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	11.7	13.5	8.4	16.7	28.8	<0.2
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	5	6	<5	5	5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	10	11	<10	14	19	<10

Table 45. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION I5

Parameter	Units	June 1975			October 1975		
		Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.2	0.2	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.5	1.1	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	0.4	1.1	<0.2	<0.2	<0.2	<0.2
4-Hydroxylamino-2,6-Dinitrotoluene	μg/l	23	69	<5	<5	<5	<5
2-Hydroxylamino - 4,6-Dintrotoluene	μg/l	32	112	<10	<10	<10	<10

Table 46. IOWA ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA
INDUSTRIAL STATION I7

		June 1975			October 1975		
Parameter	Units	Mean	Max.	Min.	Mean	Max.	Min.
2,6-Dinitrotoluene	μg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	μg/l	0.2	0.3	<0.1	<0.1	<0.1	<0.1
1,3,5-Trinitrobenzene	μg/l	0.3	0.5	<0.2	<0.2	<0.2	<0.2
2,4,6-Trinitrotoluene	μg/l	3.4	8.9	<0.2	6.0	20.9	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	μg/l	7	12	<5	11	34	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	μg/l	11	14	<10	20	54	<10

research in our own laboratories. Compounds such as the hydroxylamino-dinitrotoluenes and aminodinitrotoluenes, thought at one time to be major transformation products, are now believed to be only intermediates in the pathway of chemical reduction for alpha TNT. The formation of diamine derivatives is the next subject for consideration. The toxicity of all these transformation products is also of major concern. Obviously the environmental fate and effects of extremely reactive compounds such as TNT cannot be accurately assessed by looking only at the parent compound.

Sediment Phase

General Chemistry -

Characterization of the bottom sediment deposits is an important part of any aquatic survey. Not only does the sediment chemistry significantly affect the biota normally associated with bottom deposits, but in a chemical sense the sediments can serve as a source or sink for constituents found in the aqueous phase. At the IAAP three core samples were collected at each stream station during each survey period. In general, these core samples can be considered replicates since they were taken within a single sediment formation and usually were withdrawn within a one half meter radius. However, at certain stations several sediment types could be found, and in an attempt to obtain sediment characteristics representative of the general sampling area, cores were taken in one or more of the sediment formations present. The variation about the mean for samples from such a station will be predictably greater than for those cores taken from a station where only one major sediment formation exists. For this reason, the physical description of sediment cores listed in Tables 47 through 50 are important considerations when comparing the sediment chemistry of one station with another, or even when comparing "replicate" core samples taken at a given station.

Mean values for general sediment chemistry parameters are presented in Tables 51 and 52 for the summer survey period, and Tables 53 and

Table 47. SEDIMENT DESCRIPTION
IOWA ARMY AMMUNITION PLANT 25 JUNE 1975
BRUSH CREEK STATIONS

Sample	Sampling Device	Sediment Depth	Color	Fraction $>$841 um	Description
B1-1	Corer	0-10 cm	Dark Brown	3.6%	Soil
B1-2	Corer	0-10 cm	Black	1.8%	Soil
B1-3	Corer	0-10 cm	Black	2.3%	Soil
	Corer	10-16 cm	Black	0.0%	Soil
B2-1	Corer	0-10 cm	Brown	41.4%	Sand, stones and coal fragments
	Corer	10-20 cm	Brown	33.7%	Sand, gravel and detritus
	Corer	20-28 cm	Brown	36.2%	Sand, clay and some detritus
B2-2	Corer	0-10 cm	Brown	47.9%	Sand
	Corer	10-20 cm	Brown	14.3%	Sand, silt and detritus
B2-3	Corer	0-10 cm	Brown	25.1%	Gravel with detritus
	Corer	10-20 cm	Dark Brown	2.0%	Sand overlying detritus
	Corer	20-30 cm	Brown	2.5%	Clay with detritus
B3-1	Corer	0-10 cm	Brown	29.2%	Coarse sand overlying clay;stones
B3-2	Corer	0-10 cm	Brown	41.5%	Gravel with clay
B3-3	Corer	0-10 cm	Brown	12.0%	Coarse sand
B4-1	Corer	0-10 cm	Brown	18.6%	Coarse sand with detritus
	Corer	10-18 cm	Brown	35.1%	Sand, clay, stones and detritus
B4-2	Corer	0-10 cm	Brown	11.9%	Ooze with detritus
	Corer	10-20 cm	Brown	14.2%	Sand, ooze and detritus
	Corer	20-26 cm	Brown	21.4%	Sand and ooze

Table 47 (continued).

Sample	Sampling Device	Sediment Depth	Color	Fraction > 841 µm	Description
B4-3	Corer	0-10 cm	Dark Brown	7.7%	Ooze with detritus
	Corer	10-20 cm	Dark Brown	1.9%	Sand and clay with detritus
B5-1	Corer	0-10 cm	Brown	22.7%	Coarse sand
	Corer	10-20 cm	Brown and Gray	49.4%	Coarse sand, clay, stones and detritus
	Corer	20-30 cm	Brown	0.2%	Sand with clay
B5-2	Corer	0-10 cm	Brown	19.3%	Sand
	Corer	10-20 cm	Brown and Gray	38.4%	Sand with clay; stones
	Corer	20-30 cm	Gray	6.6%	Clay
B5-3	Corer	0-10 cm	Brown	22.7%	Sand, clay and detritus
	Corer	10-20 cm	Brown	40.2%	Sand with detritus
	Corer	20-28 cm	Brown	37.4%	Sand with detritus
B6-1	Corer	0-10 cm	Brown	23.1%	Coarse sand
	Corer	10-20 cm	Brown	3.5%	Sand
B6-2	Corer	0-10 cm	Brown	26.9%	Coarse sand
	Corer	10-20 cm	Brown	3.7%	Sand with clay
	Corer	20-30 cm	Brown	0.0%	Coarse sand with clay
B6-3	Corer	0-10 cm	Brown	19.6%	Coarse sand
	Corer	10-20 cm	Brown	12.2%	Coarse sand and clay
	Corer	20-28 cm	Gray	0.0%	Clay
B7-1	Corer	0-10 cm	Brown	6.6%	Sand
	Corer	10-19 cm	Brown	25.0%	Coarse sand with stones

Table47 (continued).

Sample	Sampling Device	Sediment Depth	Color	Fraction 841 µm	Description
B7-2	Corer	0-10 cm	Brown	14.4%	Coarse Sand
	Corer	10-20 cm	Brown	19.0%	Coarse sand, stones and detritus
	Corer	20-30 cm	Brown	42.9%	Coarse sand and detritus
B7-3	Corer	0-10 cm	Brown	19.1%	Sand
	Corer	10-20 cm	Brown	43.4%	Sand with large stones
	Corer	20-26 cm	Brown	33.2%	Sand with detritus
B8-1	Corer	0-10 cm	Brown	32.4%	Coarse sand, clay and stones
B8-2	Corer	0-9 cm	Brown	15.6%	Coarse sand and clay
B8-3	Corer	0-10 cm	Brown	44.0%	5 cm gravel overlying 5 cm clay

Table 48. SEDIMENT DESCRIPTION
IOWA ARMY AMMUNITION PLANT 25 JUNE 1975
SPRING CREEK STATIONS

Sample	Sampling Device	Sediment Depth	Color	Fraction > 841 μm	Description
S1-1	Corer	0-6 cm	Brown	27.5%	Sand
S1-2	Corer	0-10 cm	Brown	32.7	Coarse sand with stones
S1-3	Corer	0-10 cm	Brown	16.5	Sand
S2-1	Corer	0-10 cm	Brown	18.8	Coarse sand

Table 49. SEDIMENT DESCRIPTION
IOWA ARMY AMMUNITION PLANT 15 OCTOBER 1975
BRUSH CREEK STATIONS

Sample	Samling Device	Sediment Depth	Color	Fraction 841 µm	Description
B1-1	Corer	0-10 cm	Black	17.8%	Soil with detritus
B1-2	Corer	0-10 cm	Black	0.4%	Soil
B1-3	Corer	0-10 cm	Black	4.6%	Soil
B2-1	Corer	0-10 cm	Dark Brown	42.4%	Coarse sand with detritus
	Corer	10-20 cm	Dark Brown	46.7%	Coarse sand, clay and detritus
	Corer	20-27 cm	Brown and Gray	5.2%	Clay
B2-2	Corer	0-10 cm	Brown	37.4%	Sand with detritus and coal
	Corer	10-20 cm	Brown	44.3%	Coarse sand
	Corer	20-33 cm	Light Brown	17.1%	Coarse sand overlying clay
B2-3	Corer	0-10 cm	Dark Brown	43.5%	Coarse snad with detritus
	Corer	10-20 cm	Dark Brown	19.2%	Coarse sand
	Corer	20-27 cm	Brown	33.6%	Coarse sand with clay
B3-1	Corer	0-10 cm	Dark Brown	18.2%	Detritus with fine sand
	Corer	10-20 cm	Brown	60.4%	Coarse gravel, sand and clay
	Corer	20-30 cm	Light Brown	46.1%	Gravel with coarse sand
B3-2	Corer	0-10 cm	Gray	50.9%	5 cm sand overlying 5 cm clay; stones
	Corer	10-20 cm	Gray	41.5%	Coarse sand
	Corer	20-30 cm	Gray	21.0%	Clay with detritus

Table 49 (continued).

Sample	Sampling Device	Sediment Depth	Color	Fraction 841 µm	Description
B3-3	Corer	0-10 cm	Dark Brown	10.3%	Sand with detritus
	Corer	10-20 cm	Brown	42.0%	Sand, clay and detritus
	Corer	20-26 cm	Brown	67.3%	Gravel
B4-1	Corer	0-10 cm	Brown and green	19.8%	Sand
	Corer	10-20 cm	Gray	8.8%	Clay
	Corer	20-26 cm	Brown	37.4%	Coarse sand
B4-2	Corer	0-10 cm	Brown	33.6%	Coarse sand
	Corer	10-18 cm	Brown	50.2%	Coarse sand with large rocks, some coal
B4-3	Corer	0-10 cm	Brown and green	21.9%	Gravel and clay
	Corer	10-20 cm	Brown and green	12.9%	Clay
	Corer	20-30 cm	Brown	44.1%	Coarse sand
B5-1	Corer	0-10 cm	Brown	19.6%	Sand with some coal
	Corer	10-20 cm	Brown and gray	17.0%	5 cm sand overlying 5 cm clay
	Corer	20-25 cm	Light Gray	0.0%	Clay
B5-2	Corer	0-10 cm	Brown	13.4%	Coarse sand with clay
	Corer	10-20 cm	Brown	11.1%	Coarse sand with clay
	Corer	20-30 cm	Brown and gray	0.1%	Clay
B5-3	Corer	0-10 cm	Brown	19.2%	Sand
	Corer	10-20 cm	Gray	25.6%	Clay

Table 49 (continued).

Sample	Sampling Divice	Sediment Depth	Color	Fraction 841 µm	Description
B6-1	Corer	0-10 cm	Brown	38.6%	Coarse sand with gravel
	Corer	10-20 cm	Dark Brown	52.9%	Gravel, sand and coal
B6-2	Corer	0-10 cm	Vary	49.1%	Coarse sand with detritus
	Corer	10-20 cm	Gray	7.2%	Clay with detritus
	Corer	20-26 cm	Gray and Brown	19.8%	Clay with detritus
B6-3	Corer	0-10 cm	Brown	47.6%	Coarse sand with some coal
	Corer	10-20 cm	Brown	44.5%	Coarse sand with some coal
	Corer	20-24 cm	Gray	6.9%	Ooze with detritus
B7-1	Corer	0-10 cm	Dark Brown	25.5%	Sand and silt
	Corer	10-20 cm	Dark Brown	7.3%	Silt and clay
B7-2	Corer	0-10 cm	Dark Brown	18.9%	Sand overlying ooze
	Corer	10-21 cm	Dark Brown	4.5%	Interspersed layers of sand and ooze
B7-3	Corer	0-10 cm	Brown	17.8%	Sand
	Corer	10-20 cm	Brown and Gray	10.4%	Sand and clay
B8-1	Corer	0-10 cm	Brown	20.0%	Sand with detritus
	Corer	10-14 cm	Brown	15.2%	Coarse sand
B8-2	Corer	0-10 cm	Brown	14.5%	Ooze overlying sand
	Corer	10-21 cm	Brown	20.6%	Sand with some coal
B8-3	Corer	0-10 cm	Brown	9.2%	Coarse sand
	Corer	10-16 cm	Brown	15.2%	Coarse sand

Table 50 . SEDIMENT DESCRIPTION
IOWA ARMY AMMUNITION PLANT 15 OCTOBER 1975
SPRING CREEK STATIONS

Sample	Sampling Device	Sediment Depth	Color	Fraction 841 μm	Description
S1-1	Corer	0-10 cm	Black	3.8%	Silt with detritus
	Corer	10-15 cm	Black	1.0%	Silt with detritus
S1-2	Corer	0-10 cm	Gray	30.5%	Coarse sand
	Corer	10-18 cm	Gray to Brown	52.2%	Sand
S1-3	Corer	6-10 cm	Brown	38.0%	Sand
S2-1	Corer	0-5 cm	Brown	33.4%	Coarse sand and gravel
S2-2	Corer	0-10 cm	Brown	11.7%	Sand
S2-3	Corer	0-10 cm	Brown	28.4%	Sand with detritus

Table 51 . IOWA ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
BRUSH CREEK STATIONS: 0-10 cm SECTION MEANS
25 June 1975

		Station							
Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
Total Solids	%	74.3	82.2	82.2	75.9	84.6	84.1	82.7	82.0
Total Volatile Solids	% dry weight	10.1	10.8	3.2	6.3	2.1	1.6	2.4	3.3
COD	mg/g	70	110	16	44	20	12	27	8
Hexane Extractables	mg/kg	370	910	160	310	270	130	220	180
Kjeldahl-N	mg/kg	1660	1450	330	970	300	190	430	230
Nitrate + Nitrite-N	mg/kg	440	520	410	500	280	320	290	200
Total Phosphorus	mg/kg	750	960	1030	780	600	530	610	740
Cadmium	mg/kg	1	1	1	1	1	<1	1	1
Chromium	mg/kg	11.6	20.7	12.9	31.3	17.8	35.3	43.7	14.3
Iron	mg/g	11.6	16.3	12.6	11.9	7.2	6.8	6.3	8.2
Mercury	mg/kg	0.04	0.10	0.06	0.15	0.09	0.11	4.54	0.03
Manganese	mg/kg	1140	1370	1150	1310	680	980	1050	590
Lead	mg/kg	21	25	16	30	16	15	19	23

Table 52. IOWA ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
SPRING CREEK STATIONS: 0-10 cm SECTION MEANS
25 June 1975

Parameter	Units	Station S1	Station S2
Total Solids	%	69.1	81.6
Total Volatile Solids	% dry weight	3.1	1.6
COD	mg/g	13	4
Hexane Extractables	mg/kg	210	110
Kjeldahl-N	mg/kg	550	220
Nitrate + Nitrite-N	mg/kg	310	81
Total Phosphorus	mg/kg	790	180
Cadmium	mg/kg	1	<1
Chromium	mg/kg	5.4	4.5
Iron	mg/g	11.2	3.9
Mercury	mg/kg	0.03	0.02
Manganese	mg/kg	1800	450
Lead	mg/kg	21	19

Table 53. IOWA ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
BRUSH CREEK STATIONS: 0-10 cm SECTION MEANS
15 October 1975

Parameter	Units	Station B1	B2	B3	B4	B5	B6	B7	B8
Total Solids	%	72.8	77.1	76.5	71.6	82.9	80.1	80.8	80.2
Total Volatile Solids	% dry weight	9.1	7.5	3.8	8.4	1.3	3.2	3.3	2.7
COD	mg/g	47	64	29	79	9	19	13	15
Hexane Extractables	mg/kg	140	170	270	420	130	220	130	200
Kjeldahl-N	mg/kg	1580	990	660	1560	220	300	560	410
Nitrate + Nitrite-N	mg/kg	160	170	210	160	130	170	140	170
Total Phosphorus	mg/kg	710	760	720	990	290	710	400	360
Cadmium	mg/kg	1	<1	<1	1	<1	< 1	1	1
Chromium	mg/kg	10.7	26.0	26.7	54.5	11.8	55.1	7.4	15.9
Iron	mg/g	11.7	12.6	8.0	10.9	4.1	7.3	6.5	5.4
Mercury	mg/kg	0.03	0.08	0.09	0.09	0.03	0.02	0.24	0.03
Manganese	mg/kg	1170	830	370	580	420	670	320	510
Lead	mg/kg	23	23	16	19	6	16	8	10

Table 54. IOWA ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
SPRING CREEK STATIONS: 0-10 cm SECTION MEANS
15 October 1975

Parameter	Units	Station S1	S2
Total Solids	%	78.6	80.0
Total Volatile Solids	% dry weight	3.9	1.6
COD	mg/g	21	7
Hexane Extractables	mg/kg	240	170
Kjeldahl-N	mg/kg	830	230
Nitrate + Nitrite-N	mg/kg	150	150
Total Phosphorus	mg/kg	450	250
Cadmium	mg/kg	<1	<1
Chromium	mg/kg	5.0	2.6
Iron	mg/g	7.8	4.6
Mercury	mg/kg	0.02	0.01
Manganese	mg/kg	590	340
Lead	mg/kg	15	22

54 for the October sampling. Discrete analytical results for each of the core samples taken during both surveys are presented in Appendices VII and VIII. In comparing the concentrations of various parameters in Brush Creek with background levels normally anticipated for such streams, it is not completely justifiable to use stream station B1 as a control. This is due to the fact that the sediment at B1 can be accurately described as rich topsoil. Such a bottom material is uncharacteristic of continuously flowing streams. Rather, a drainage ditch with low and intermittent flow is suggested. This is also true, though to a lesser extent, for Spring Creek station S1. The bottom deposits of such drainage ditches collect excessive amounts of nutrient-rich silt. For this reason, Spring Creek station 2 provides a better comparison for sediments taken from stations in Brush Creek where flow is continuous.

Sediments from stations B2, B3 and B7 show the most significant increases above background levels during the June survey. Elevated levels of hexane extractables, Kjeldahl-nitrogen, total phosphorus, chromium, and mercury observed at station B7 can be attributed,to a large extent, to the effluent discharged from the IAAP domestic wastewater plant. The mean concentration of mercury here is particularly noteworthy. Increases in most of the general sediment chemistry parameters observed at stations B2 and B4 can be attributed to the activities associated with IAAP production lines. These increases involve primarily nitrogen, phosphorus and organic carbon concentrations. Certain metals, including chromium, iron, mercury and lead, are also enriched as a result of these activities.

The sediment samples collected during October also reflect this trend of enrichment, with stations B2 and B4 generally showing the greatest increases in those general sediment chemistry parameters monitored. Similarly, core samples from station B8 taken during both summer and fall surveys reveal that the general sediment quality improves to near background conditions as the stream descends to the IAAP boundary.

Munitions Compounds -
Average concentrations for munitions-related compounds in the IAAP sediments are presented in Tables 55 through 58. A review of the summer survey data reveals that detectable quantities of munitions compounds and specific transformation products were found at stations B2, B4, B5, B6 and B7. As during the 1974 survey period, station B4 contained the greatest quantities of 2, 4, 6 - trinitrotoluene of all Brush Creek stations. Station B2, which was the intended control station for the 1974 survey, was also found to contain significant concentrations of TNT and transformations products, presumably originating from industrial outfalls 3 and 4. It is interesting to note that no munitions - related compounds were detected in sediments from stream station B8 collected during the 1975 summer survey.

Analysis of sediments collected in October revealed munitions - related compounds at stations B2, B4, B5, B6, B7 and B8. Again during this survey, station B4 had the highest average 2,4, 6 - TNT concentration of any stream sediment sampled. Indeed, one core from this station contained over 200 mg/kg of alpha TNT. Sediment concentrations of all munitions-related compounds declined downstream of station B4, though during the fall survey some residue was still detectable at station B8.

During the summer survey, an additional source of munitions - related compounds was discovered along Brush Creek. Situated on the east side of the stream, approximately 950 meters downstream of B3 and 250 meters upstream of B4, a large vegetation-free plateau was found. The entire plateau was highly eroded and the barren soil was reddish in color. Plant personnel were queried as to the history of this area and it was learned that it was previously the site of a "pink-water" treatment lagoon. Process water from the TNT operations of Group 1 were collected in this lagoon, which actually was a retention pond in Brush Creek itself. Since the wastewater was acidic, flyash from the then coal-burning power plant was also dumped into the lagoon to help neutralize the acidic wastes. Considerable amounts of solid coal-wastes were dumped into the lagoon

Table 55. SEDIMENT PHASE MUNITIONS DATA
IOWA ARMY AMMUNITION PLANT 25 JUNE 1975
BRUSH CREEK STATIONS: 0-10 cm SECTION MEANS

Parameter	Units	B1	B2	B3	B4	B5	B6	B7	B8
2,6-Dinitrotoluene	mg/kg	<0.1	2.4	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
2,4-Dinitrotoluene	mg/kg	<0.4	<0.1	<0.1	0.1	<0.1	0.1	0.2	<0.1
1,3,5-Trinitrobenzene	mg/kg	<1.3	3.5	<1.0	1.4	<1.0	1.2	<1.0	<1.0
2,4,6-Trinitrotoluene	mg/kg	<1.0	9.0	<0.2	18.7	0.3	1.0	2.7	<0.2
4-Hydroxylamino-2,6-Dinitrotoluene	mg/kg	<5	8	<5	9	<5	<5	<5	<5
2-Hydroxylamino-4,6-Dinitrotoluene	mg/kg	<30	90	<30	45	<30	<30	<30	<30

Table 56 . IOWA ARMY AMMUNITION PLANT

SEDIMENT PHASE MUNITIONS DATA

SPRING CREEK STATIONS: 0-10 cm SECTION MEANS

25 JUNE 1975

Parameter	Units	Station	
		S1	S2
2,6-Dinitrotoluene	mg/kg	<0.1	<0.1
2,4-Dinitrotoluene	mg/kg	<0.2	<0.2
1,3,5-Trinitrobenzene	mg/kg	<1.0	<1.0
2,4,6-Trinitrotoluene	mg/kg	<0.7	<0.2
4-Hydroxylamino - 2,6-Dinitrotoluene	mg/kg	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	mg/kg	<32	<30

Table 57 . IOWA ARMY AMMUNITION PLANT

SEDIMENT PHASE MUNITIONS DATA

BRUSH CREEK STATIONS: 0-10 cm SECTION MEANS

15 OCTOBER 1975

Parameter	Units	Station B1	B2	B3	B4	B5	B6	B7	B8
2,6-Dinitrotoluene	mg/kg	<0.2	0.3	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
2,4-Dinitrotoluene	mg/kg	<0.3	<0.1	<0.1	0.9	0.1	0.3	0.1	<0.1
1,3,5-Trinitrobenzene	mg/kg	<3.7	1.6	<1.0	2.0	<1.0	5.1	<1.0	1.3
2,4,6-Trinitrotoluene	mg/kg	<0.2	2.6	<0.2	111	2.0	2.0	0.3	0.4
4-Hydroxylamino 2,6-Dinitrotcluene	mg/kg	<5	<5	<5	57	<5	<5	<5	<5
2-Hydrcxylamino-4,6-Dinitrotoluene	mg/kg	<43	44	<30	101	33	<30	<30	<30

Table 58 . IOWA ARMY AMMUNITION PLANT
SEDIMENT PHASE MUNITIONS DATA
SPRING CREEK STATIONS: 0-10 cm SECTION MEANS
15 OCTOBER 1975

Parameter	Units	Station	
		S1	S2
2,6-Dinitrotoluene	mg/kg	<0.1	<0.1
2,4-Dinitrotoluene	mg/kg	<0.4	<0.2
1,3,5-Trinitrobenzene	mg/kg	<4.0	<1.0
2,4,6-Trinitrotoluene	mg/kg	<0.2	0.3
4-Hydroxylamino - 2,6-Dinitrotoluene	mg/kg	<5	<5
2-Hydroxylamino - 4,6-Dinitrotoluene	mg/kg	<50	<30

with the idea that a certain amount of carbon adsorption of munitions - related compounds would be attained and these adsorbed materials would be thus transported from the aqueous phase to the bottom sediments. Spill-over from the lagoon simply continued down Brush Creek to another treatment installation located under the bridge in Road H near the IAAP sewage disposal plant, where excess acidity was neutralized with the addition of base.

According to contractor personnel, the lagoon was allowed to go into a state of disrepair and has been used for approximately 20 years. This date coincides with the initial use of physiochemical waste treatment of munitions - related wastewaters at the IAAP. Given the long period of time since large amounts of TNT were added to the lagoon, it is somewhat surprising to find over 3000 mg/kg of the highly reactive 2, 4, 6 - isomer present in soil there today. A sample of this barren soil was collected during the June survey and analyzed only for munitions - related compounds. The results are presented in Table 59. Soil from this barren area, dubbed "TNT Flats" by the field survey crew, contains large amounts of the hydroxylamine transformation products in addition to 2, 4, 6 - TNT.

It was observed during the 1974 survey and during both 1975 surveys that, after a rainfall, small puddles of "pink-water" would collect at high water areas of downstream stations in Brush Creek, especially at station B4. Given the denuded and highly eroded physical nature of the "TNT Flats" area, it seems likely that leachate from this area is responsible for these puddles. Further, since the sediments at station B5 do not show the same level of munitions compounds enrichment as those at B4, despite the fact that Group 2 is perhaps the busiest conventional munitions processing operation along Brush Creek, it seems likely that leachate from the "TNT Flats" area is responsible for the very high concentrations of munitions-related compounds observed in the B4 sediments. Indeed, this leachate should probably be considered a significant source of such compounds throughout the downstream areas of Brush Creek.

Table 59. SEDIMENT PHASE MUNITIONS DATA FROM "TNT FLATS" NEAR IOWA ARMY AMMUNITION PLANT STATION B4

Parameter	Concentration (mg/kg)
2,6-Dinitrotoluene	0.5
2,4-Dinitrotoluene	3.0
1,3,5-Trinitrobenzene	0.6
2,4,6-Trinitrotoluene	3030
4-Hydroxylamino-2,6-Dinitrotoluene	101
2-Hydroxylamino-4,6-Dinitrotoluene	180

Another area of very high concentrations of munitions compounds was found near the IAAP Group 800. A large impoundment of "pink-water", used primarily as a wastewater storage area, is situated just east of the Group 800 security fence. Sediment samples taken from this impoundment approximate the same level of munitions related compounds as soil samples from the "TNT Flats". A breach in the diking system around this impoundment during 1974 may well be responsible for "pink-water" puddles observed at downstream Brush Creek stations during the 1974 field survey. The diking system has been rebuilt and was intact throughout both 1975 survey periods. Conflicting stories were obtained from IAAP personnel concerning the present utility of this impoundment.

In order to summarize the effects of IAAP production lines on the level of munitions - related compounds in the Brush Creek system, average concentrations found in the aqueous and sediment phases during the summer and fall surveys are found in Figures 9 and 10 respectively.

Figure 9. Mean Concentration of 2,4,6-Trinitrotoluene During the June 1975 Survey.

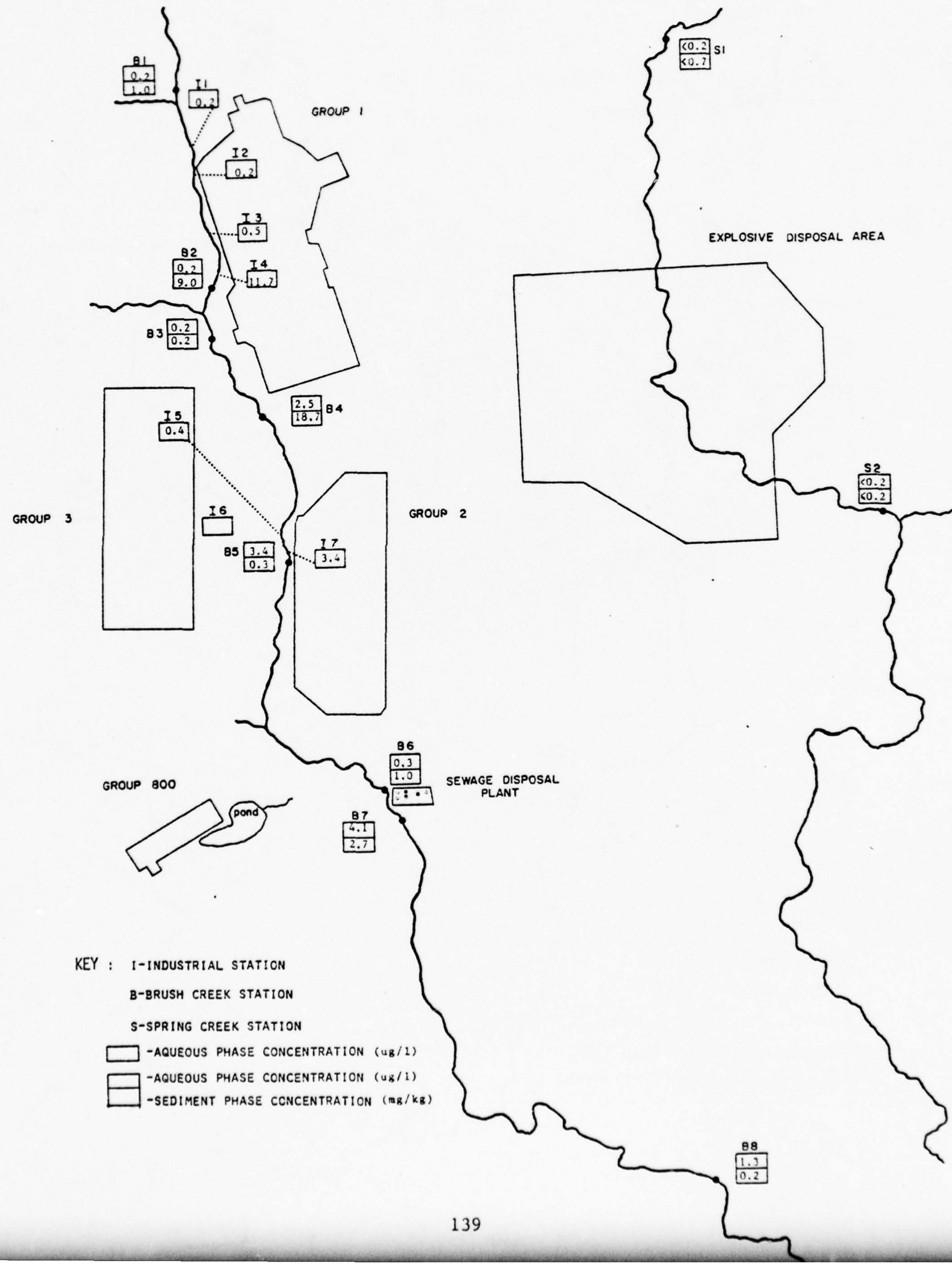
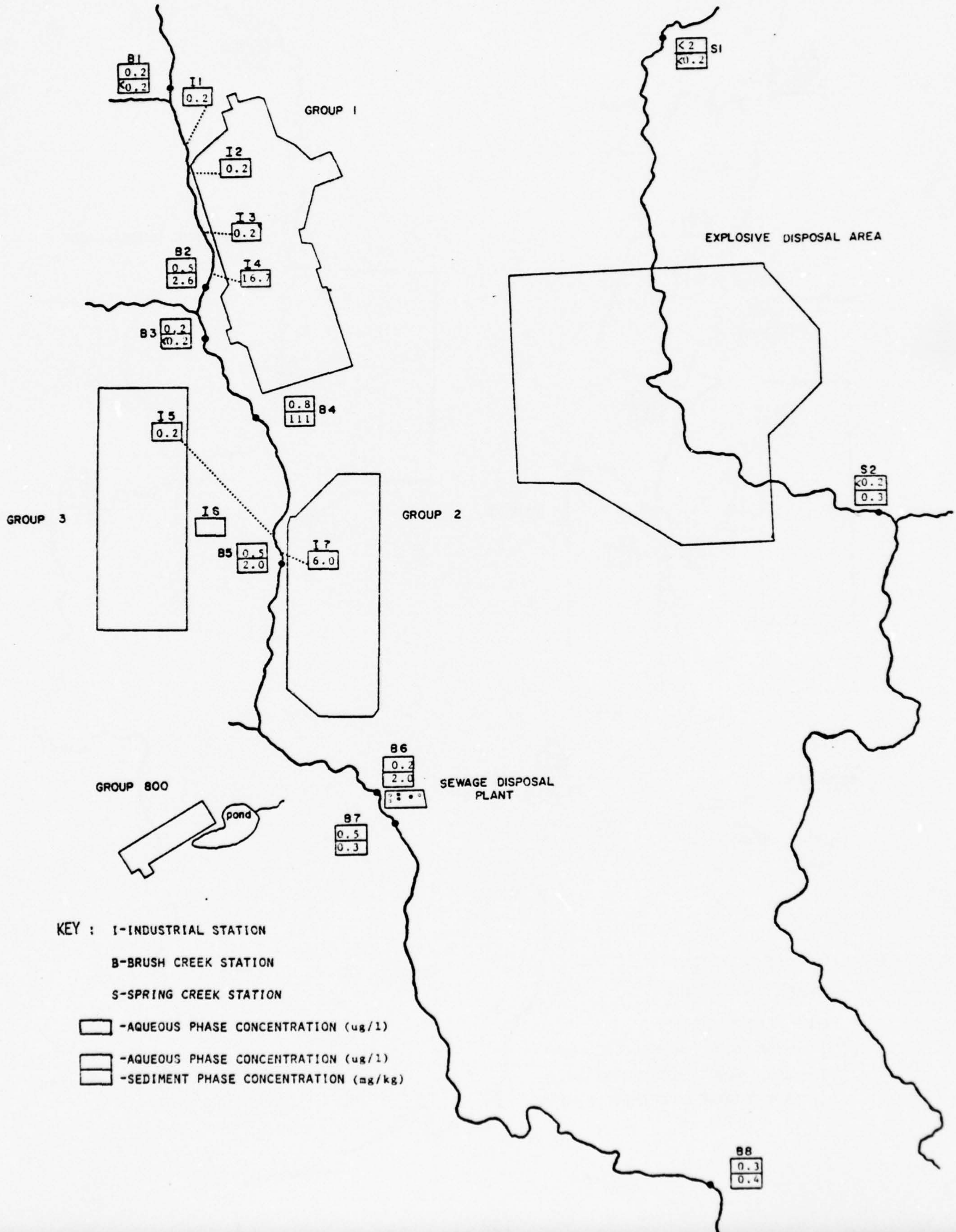


Figure 10. Mean Concentration of 2,4,6-Trinitrotoluene During October 1975 Survey.



SECTION VII

BIOLOGY

DATA ANALYSES

Population Indices

Various mathematical expressions of population diversity were used in comparing the associations of species from the collected samples[23,24,25]. Collectively referred to as species diversity indices, these expressions have been used as successful tools for the assessment of the effects of pollution on aquatic biota[23, 26, 27]. In this survey several indices were applied to the species data in comparisons of replication and as comparisons of species associations between sampling stations. Comparisons were drawn between samples collected from similar substrate types, e.g., glass slide artificial substrates between stations, and between substrate types, e.g., periphyton from rock surfaces compared to samples from artificial substrates. These comparisons were made to determine the maximum potential population available to colonize artificial substrate samplers, which were used to maintain a consistency in sampling techniques. Furthermore, since artificial substrates are somewhat selective, these comparisons would indicate possible effects over a wider range of organisms as well as showing effects on species that are in more direct contact with substrates which could sorb the pollutants in question.

Species Diversity -

The Shannon expression (Shannon-Weaver), which is based on information theory, was used to measure species diversity[25, 27,28]. This index is not as closely related to the number of individuals per sample as other

formulas and is therefore useful in comparing populations represented by varied sample sizes[23]. The Shannon-Weaver diversity expression has been criticized because it is apparently insensitive to the uncommon and rare species, although the significance of rare species to community production is limited, if not questionable[29]. Shannon's diversity is expressed as, $H' = - \sum_{i=1}^{s} \frac{ni}{N} \text{ loge } \frac{ni}{N}$

where:

H' = community diversity

N = total number of organisms

n = number of individuals per taxon

s = total number of species in a unit area

As a point of reference, species diversity values increase as the number of different species in a community increases, while diversity approaches zero when all individuals belong to just a few species[29].

Species Evenness -

In addition to the expression of species diversity, a corresponding evenness expression was also applied to the species data. Evenness (J), which is a measure of the dominance of one or more species, was used as opposed to the similar expression of redundancy (r)[24,25,27,28].

Evenness is expressed as, $J = \frac{H'}{H\ max} = \frac{H'}{\log S}$

where:

$$H\ max = \left(\frac{1}{N}\right) \left[\log_2 N! - S\log_2 \left(\frac{N}{S}\right)!\right]$$

Eveness (J) is inversely proportional to redundancy (r) and will tend to parallel species diversity. As pollution increases and there is a corresponding shift to a large number of individuals represented by few taxa, there will be a high redundancy (r) and a low diversity (H') with low evenness (J). Under clean water conditions species diversity and evenness will tend to be high while redundancy is low[25].

Truancated Normal Curve -

This method of comparison was applied to diatom species data although its usefullness was limited by the number of specimens counted[28,30,31]. The truncated normal curve is typically applied to data acquired through "long counts" of 5,000, 8,000, or 10,000 diatoms [28]. Diatom data generated throughout this survey was based on "short counts" of 500 diatoms on each of the sample replicates. These data were then combined to yield effective counts of 1,500 diatoms and 2,500 diatoms respectively for the enumeration of three and five replicates. Similar to species diversity indices, the truncated normal curve reflects the typical increase of total numbers of individuals with reduced number of total species in response to pollutants[26,28,32].

Coefficient of Similarity

Another means of comparing the biological communities under study was the measurement of the degree of similarity between species associations at different sampling stations. The coefficient of similarity was also used to indicate the degree of likeness between replicate samples. Many researchers have realized that in addition to community structure (i.e., species diversity), similarity of species occurrence is likewise significantly important [26,29,30,33]. One assumes that given identical physico-chemical conditions aquatic communities will be similar when sampled from proximal locations within the same system. This concept has been shown to hold true both with distance between stations and with time at the same station within a river system [26,30], unless influenced by waste discharges or other sources of pollution. The coefficient of similarity developed by Pinkham and Pearson [34,35], was applied to the diatom and benthic macroinvertebrate species data of this survey. Unlike other coefficients which are based on presence and absence of species, the Pinkham and Pearson coefficient utilized quantitative data of species occurrence, thereby producing a more reliable comparison of data [34].

For the comparison of replicate and station similarity of periphyton species data collected from artificial substrates, formula "B_2" of the Pinkham and Pearson Coefficient of Association was utilized. Mutual absence of species, i.e., 0/0 matches, were ignored [34, 35]. This formula is used when organisms of a sample (s) represent a single trophic level, in this case, only diatom species associations were compared. The relative abundance or frequency of occurrence is an important factor when this formula is used. In comparing populations of the same trophic level the dominance of a single species or the co-dominance of two or three species is important, especially if this dominance is altered between samples or stations.

When periphyton species associations, i.e., diatoms, were compared from samples collected from natural substrates formula "B_1" was used with 0/0 matches scored as one [34,35]. This formula is more applicable to samples collected by differing methodologies. In this case, periphyton collected from natural substrates were considered as "different methodology" since different substrate types, i.e., wood surfaces, rock surfaces, and sediment surfaces, were sampled.

PERIPHYTON

Analytical Procedures

Species Occurrence -

Species identifications of diatom and non-diatom algae were made on preparations of material collected from natural and artificial substrates. Periphyton on artificial substrates was first scraped from the slides and permitted to settle to the bottom of the sample container. Aliquots were taken from the replicate artificial substrate samples and from the natural substrate collections and processed independently of each other. One set of aliquots was held for the identification of non-diatom algae while the second set of aliquots was prepared for permanent diatom mounts.

Diatom dominance - The hydrogen peroxide/potassium dichromate procedure was used for preparing diatom material. Duplicate slide mounts were prepared from each replicate sample using Hyrax™*, mounting media [31]. Short counts of 500 diatom frustules were made on each sample replicate from the artificial substrates and from each natural substrate type. Slides were first scanned under low-power magnification (100 X) to visualize the distribution of frustules. If uneven distribution or clumping was observed the slide was discarded. Transects were made across the cover slip and all complete, i.e., non-broken, diatom frustules were identified and enumerated. From these data diatom distribution and percent dominance was determined. Data among replicates and between stations was compared through the use of species diversity, species evenness, and coefficient of similarity. Dominance of a species or species complex is discussed in terms of its relative frequency to other species. This is based on the following classification[36]:

Percent Occurrence	Relative Frequency
60-100	abundant
30-60	very common

*Custom R & D Company, Auburn, California

Percent Occurrence	Relative Frequency
5-30	common
1-5	occassional (uncommon)
1	rare

A species or species group is often referred to as being "dominant" if it has the highest level of occurrence even though its relative frequency is at the common level (5-30 percent). Therefore "dominant" does not necessarily equate with "abundant". Diatoms were identified to the species and variety level using the taxonomic keys of Hansmann, Hohn and Hellerman, Hustedt, Mayer, Patrick and Reimer, Stoermer and Yang, and Weber (Appendix IX).

Non-diatom dominance - A second set of sample aliquots was used for the identification of non-diatom algae. Each sample was concentrated and a one drop subsample was removed and placed on a glass microscope slide. Coverslips were put into place and sealed with clear fingernail polish. The slides were then dried to form semi-permanent mounts. Transects were observed using 400 X magnification and 200 algal cells were identified and enumerated. High magnification (1000 X) was used when necessary to identify some individuals to the species level. Ten cells of filamentous forms were counted as one individual. Identifications were made according to the taxonomic keys of Prescott and Smith (Appendix IX). From these counts a species list showing relative abundance was constructed.

Ash-free dry weight -
Formalin preserved samples were returned to the laboratory where the glass slide substrates were scraped with wooden toothpicks to remove the periphyton growth. This material was then filtered onto prerinsed/ preweighed Whatman GF/C glass fiber filters (4.25 centimeters diameter; 0.45 micron pore size) and rinsed with distilled water. The filtrate was dried for 24 hours at 100^{o} centigrade, weighed, ashed for one hour at

550^{o} centigrade, rehydrated with distilled water, dried at 100^{o}C, and weighed. From this information dry weight (mg/m^2), ash-free dry weight (mg/m^2), and organic weight produced (mg/m^2/day) were calculated[36,37]. Values of replicate samples were plotted and mean and standard deviation were calculated.

Chlorophyll -
Frozen samples were removed from the sample containers and tissue ground with five to eight milliliters 90 percent v/v aqueous acetone and a small amount of magnesium carbonate. Sample volume was then adjusted to ten milliliters with 90 percent aqueous acetone and centrifuged samples and adsorbance was read on a Gilford spectrophotometer. The trichromatic method was followed as described by Weber[36], and Slack, et al[38]. These data were reported as chlorophyll a (mg/m^2), chlorophyll a production (mg/m^2/day), and before acidification:after acidification ratio. Mean and standard deviation were calculated on replicate samples and these data were plotted against station location.

Autotrophic Index -
Ash-free dry weight (organic biomass) and chlorophyll a were used in a ratio which indicates the compositional development of the periphyton communities sampled. This ratio, the autotrophic index, is expressed as, organic biomass (mg/m^2)/chlorophyll a (mg/m^2) and has been used to indicate organic pollution and effluent toxicity[36,39]. The numerical value of this index increases with an increase in nonalgal biomass and decreases with an increase in algal biomass. In theory those aquatic systems receiving organic pollution will support a greater biomass of bacteria, fungi, and protozoa rather than algae, thereby raising the numerical value of this ratio (> 100). Under "clean water" conditions with a large biomass of algae the autotrophic index is numerically low, less than 100 being considered as not polluted[36,39].

Adenosine Triphosphate (ATP) -
Measurements of ATP (adenosine triphosphate) were taken from sediments and from periphyton collected on glass microscope slides at the IAAP facility. Periphyton collections were made at the 10 stations of Brush and Spring Creeks: four replicate samples were collected from three stations while single or duplicate samples were collected at the remaining seven stations. Samples were dry ice frozen in the field and taken to the laboratory for processing within 48 hours after collection.

ATP Extraction - The periphyton, which had been scraped from the glass slide substrates and filtered onto glass fiber filters, were extracted for ATP using boiling Tris buffer40. Filters with filtrate were cut into pieces to facilitate handling and placed in centrifuge tubes with 16 milliliters 0.02 M boiling Tris buffer, pH 7.78. This material was vortexed for 15 minutes then boiled for an additional four minutes. The extract was centrifuged, diluted one-tenth, and analyzed for ATP using a DuPont Model 760 Luminescence Biometer. Concentrate was determined from a standard curve and recorded as femtograms, i.e., 10^{-12} milligrams per milliliter.

This procedure was shown to be efficient and reproducible under successive experiments. The extracted ATP was stable for at least 30 minutes[40]. Other researchers have indicated that extracted ATP can be stored for long periods (30 months) if kept frozen at -20 degrees centrigrade [41]. Furthermore, the most critical period is at the time of sample collection. Samples which are frozen immediately with dry ice or liquid nitrogen yield as much as 80 percent more ATP than samples frozen and held at -20 degrees centigrade[41].

ATP comparisons - The data were related at ATP (mg/m^2), ATP/chlorophyll a, ATP/ash-free dry weight, and as conversionts of ATP to biomass and vice versa. These latter conversions were based on factors derived by other authors and reported in the literature.

The ratios of ATP to ash-free dry weight and chlorophyll a, were determined and applied in a manner similar to the autotrophic index (ash-free dry

weight/chlorophyll a). The ratio of ATP/chlorophyll a will increase as there is an increase in heterotrophic species and/or a decrease in autotrophic species, i.e., chlorophyll a. The ratio of ATP/ash-free dry weight will decrease with an increase in ash-free dry weight, i.e., heterotrophic species, especially if the source of ash-free dry weight is non-living organic material.

The following conversion factors were applied to the measured levels of ATP, and ash-free dry weight. It should be noted that most values and conversions reported in the literature are derived from laboratory cultures and are therefore free of interferences such as products of decomposition, inorganic materials, and non-viable organic particulates, i.e., detritus. It is therefore suspected that these conversion factors may be somewhat idealistic.

Biomass to ATP - Weber[39] reported that on an average there is 2.4 μg ATP/mg ash-free dry weight. The measured ATP levels ($\mu g/m^2$) were thus divided by the measured levels of ash-free dry weight (mg/m^2), and are reported as ATP (μg)/ash-free dry weight (mg). These calculated values were then compared to the value of 2.4 μg ATP reported by Weber.

Holm-Hansen[42] indicated that in algae 0.35 percent of cellular carbon was ATP but values ranged from 20 to 50 percent of 0.35 percent. This conversion was made using the measured levels of ash-free dry weight (mg/m^2). Values at 0.35 percent (0.0035) and 0.175 percent (0.00175) of the ash-free dry weight were calculated and compared to measured levels of ATP.

ATP to total cellular carbon - Holm-Hansen[43] converted ATP to total cellular carbon by using a multiplication factor of 250. Therefore, measured ATP x 250 should equal (or nearly equal) total viable organic biomass. The measured ATP levels of periphyton collected from artificial substrates was multiplied by 250 and this value, i.e., total cellular carbon (mg/m^2), was compared to the measured levels of ash-free dry weight (mg/m^2).

These conversions and ratios were then compared in an effort to indicate the viability of the periphyton microcommunity and to show effects of waste discharge on periphyton.

Results (May-June)

Species Occurrence -

Diatom dominance on artificial substrates (May-June) - The trend of diatom species diversity on artificial substrates for Brush and Spring Creeks showed an irregular pattern. Replication of the five samples collected at each station was sometimes variable. Table 60 and Figure 11 show the values of species diversity calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. Of the five replicates, usually one was different from the other four replicates at each station. This is indicated by some values occurring outside the limits of the standard deviation at each station. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) At station B1 the diatom species distribution of the five replicates was similar above the 35 percent level (Figure 12), with two replicates being similar above the 55 percent level and two other replicates being similar above the 65 percent level. It is difficult to say that the mean species diversity of 1.85 (Table 60) for the five replicates is representative of the diatom population. This is due to poor sampling conditions due to the samplers being out of the water for an unknown period of time.

2) At station B2 there were four replicate samples which had diatom species similarity above the 60 percent level (Figure 13), while the fifth replicate was similar to the other four at the 45 percent level. The mean diatom species diversity at station B2 remains at 1.80 (Table 60) even when the fifth (i.e. most different) replicate is ignored.

3) Replication of samples at station B3 was variable. One pair of replicates was similar at the 75 percent level while a second pair was similar at the 68 percent level (Figure 14). These two replicate pairs

Table 60 SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK, BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	1.61	1.66	2.49	2.44	1.16	2.21	2.81	2.31	0.54	2.20
2	2.01	1.96	2.36	2.43	1.29	2.14	2.03	2.26	0.58	2.06
3	2.00	2.02	2.50	1.79	2.20	1.65	2.81	2.41	0.55	2.55
4	1.72	1.53	2.63	2.23	2.18	2.27	2.73	2.63	1.70	2.38
5	1.90	1.81	2.71	2.50	2.20	2.39	3.07	2.20	1.79	2.31
x	1.85	1.80	2.54	2.28	1.81	2.13	2.69	2.36	1.03	2.30
s^2	0.031	0.042	0.018	0.085	0.233	0.081	0.153	0.028	0.420	0.034
s	0.177	0.204	0.136	0.291	0.532	0.285	0.391	0.168	0.652	0.185

Table 61. SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	0.63	0.54	0.79	0.77	0.39	0.69	0.83	0.69	0.28	0.72
2	0.73	0.63	0.78	0.81	0.42	0.62	0.60	0.68	0.27	0.69
3	0.72	0.63	0.75	0.61	0.65	0.55	0.83	0.71	0.25	0.77
4	0.62	0.56	0.76	0.71	0.63	0.66	0.78	0.79	0.87	0.80
5	0.72	0.58	0.79	0.71	0.66	0.68	0.82	0.66	0.81	0.73
x	0.68	0.59	0.77	0.72	0.551	0.64	0.77	0.71	0.49	0.74
s^2	0.003	0.002	0.000	0.006	0.018	0.003	0.010	0.003	0.099	0.002
s	0.054	0.041	0.018	0.076	0.133	0.057	0.098	0.050	0.315	0.043

FIGURE 11. Shannon–Weaver Species Diversity and Evenness of Periphytonton Diatoms Collected from Five Replicate Artificial Substrates. Iowa Army Ammunition Plant. Brush and Spring Creeks, Burlington Iowa.

May–June 1975

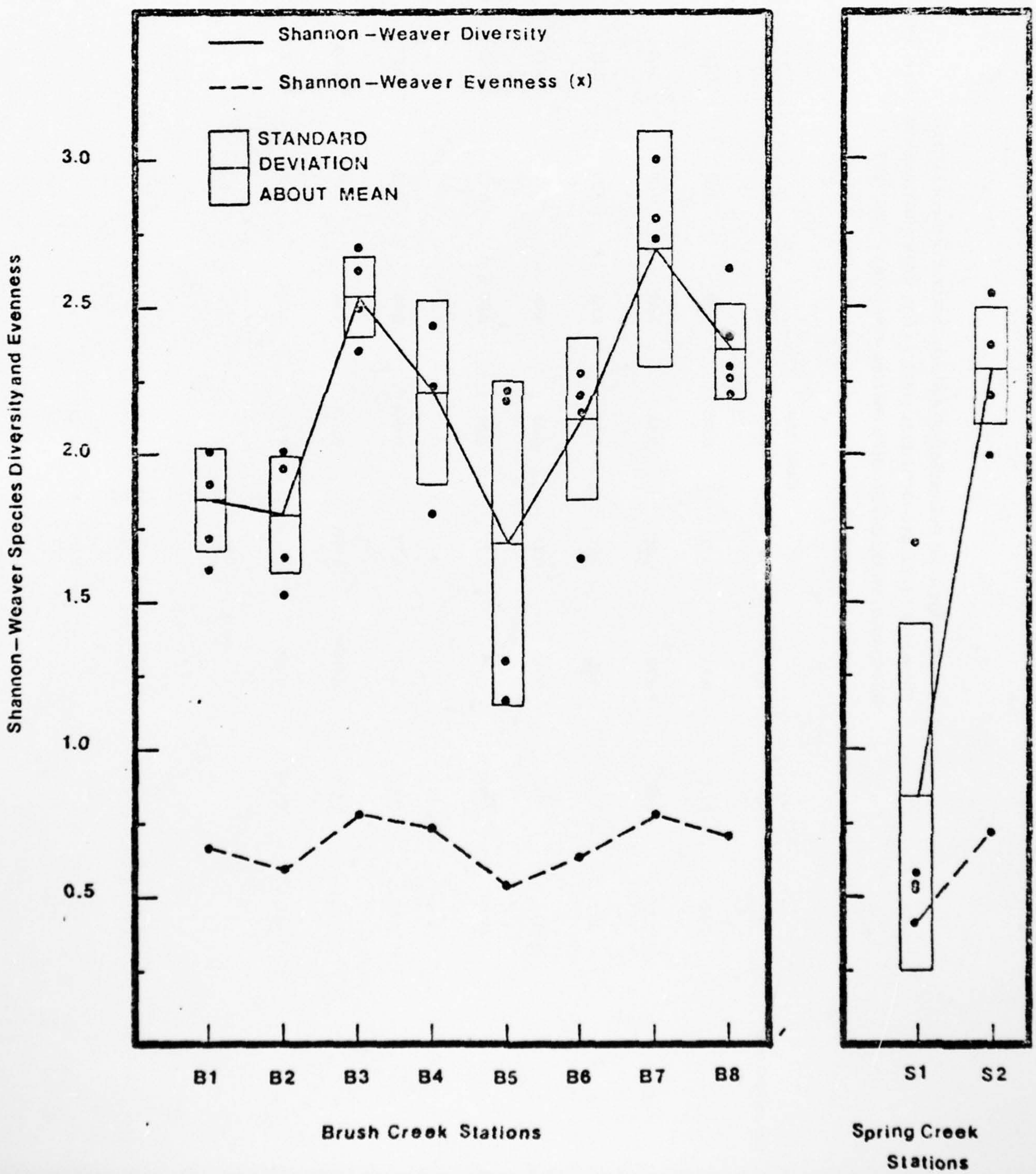


Figure 12. STATION B1-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

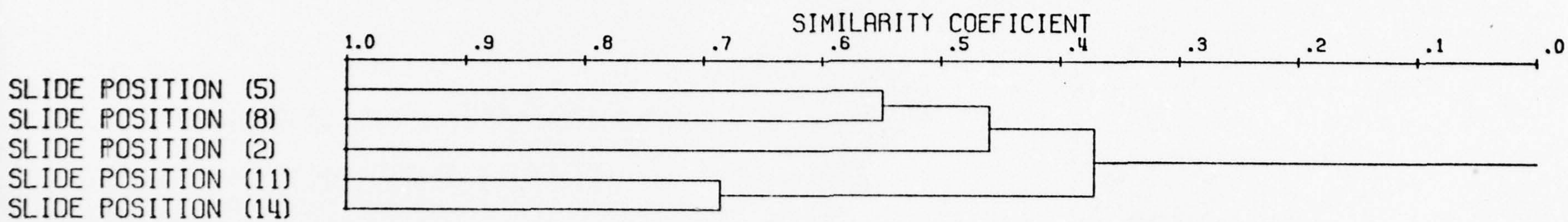


Figure 13 STATION B2-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

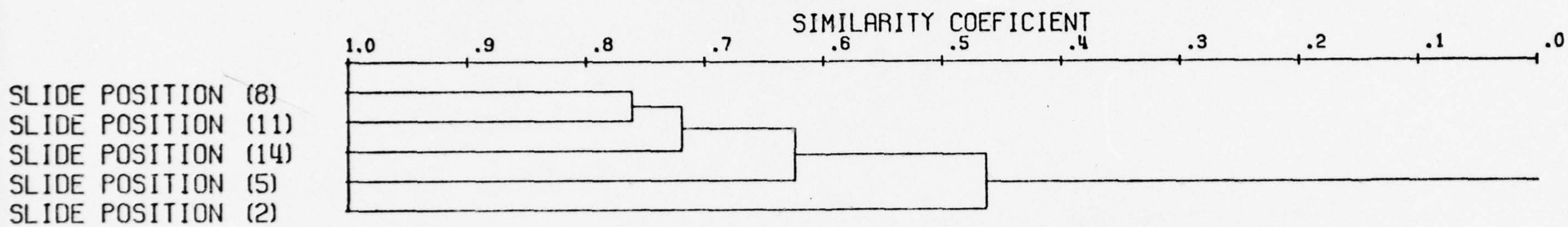
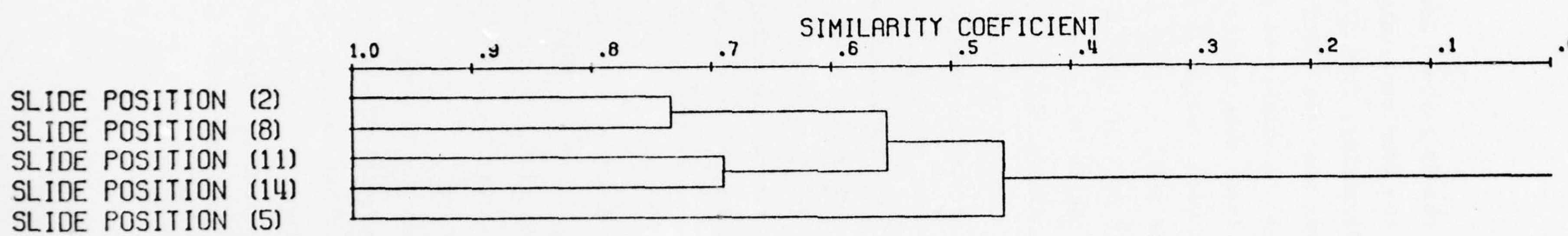


Figure 14. STATION B3-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



were similar at the 55 percent level, however the fifth replicate was only similar to the four replicates at the 45 percent level. The mean diatom species diversity, 2.54 (Table 60) is representative of the population present, even when the fifth replicate is not considered.

4) The four replicate samples at station B4 (only four replicates due to the fifth being lost) were similar at the 35 percent level (Figure 15). Three replicates were similar at the 55 percent level. When eliminating the replicate for slide position number 8, mean diatom species diversity changed from 2.28 to 2.37, only a difference of 0.09.

5) At station B5 again only four replicates were retrieved, with two replicates being similar at the 76 percent level and the other two replicates being similar at the 73 percent level (Figure 16). Both pairs of replicates were similar with each other at the 41 percent level, therefore, the mean diatom species diversity of 1.81 (Table 60) appears to be representative of the population present.

6) Station B6 showed a similarity above the 40 percent level for five replicate samples (Figure 17). Four of the replicates were similar above the 60 percent level but the elimination of one replicate did not make a significant difference on the mean diatom species diversity.

7) At station B7, replicate slide position number five was most dissimilar at the 30 percent level, while the remaining four replicates were similar above the 40 percent level (Figure 18). The mean diatom species diversity did not change appreciably from 2.69 (Table 60) when ignoring replicate slide position number five.

8) Replication of diatom species associations at station B8 (Figure 19) was similar above the 50 percent level. Four of these five replicates were similar above the 60 percent level. Ignoring slide position number 11, mean diatom species diversity at this station decreased from 2.36 to 2.30, an insignificant change.

9) Station S1 of Spring Creek had only four replicate samples retrieved. Of these four replicates, three were similar above the 90 percent level while the fourth replicate was similar to the other three at only the 10 percent level. The mean diatom species diversity at this station was

Figure 15. STATION B4-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

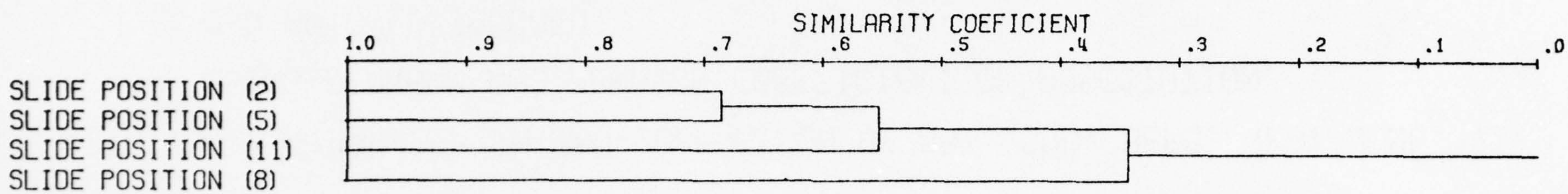


Figure 16. STATION B5-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

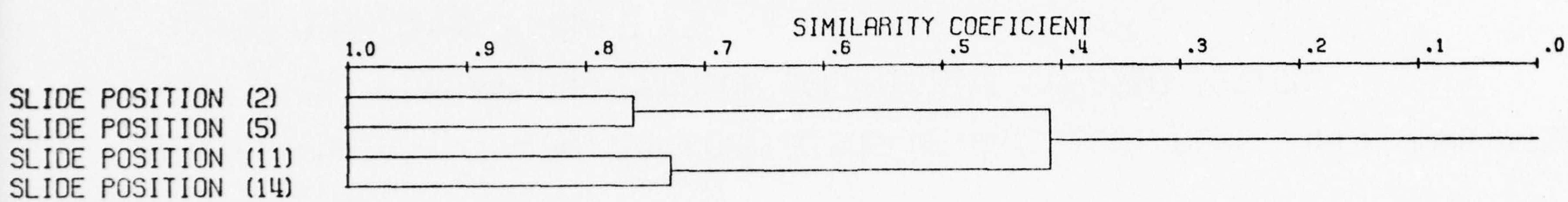


Figure 17. STATION B6-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

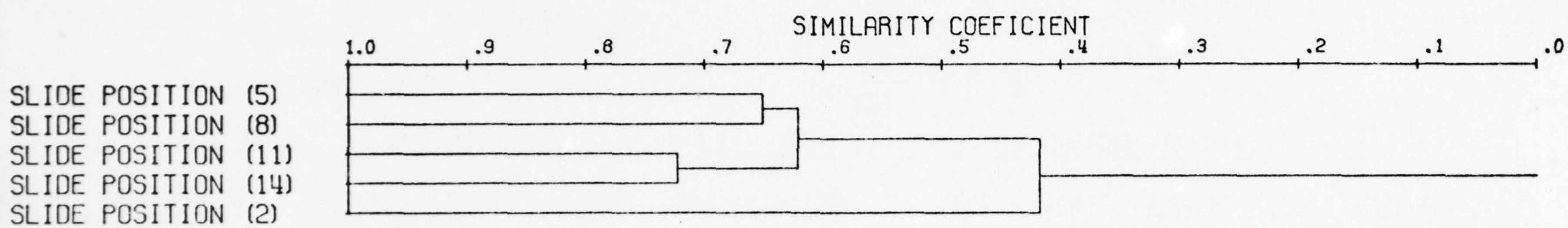


Figure 18. STATION B7-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

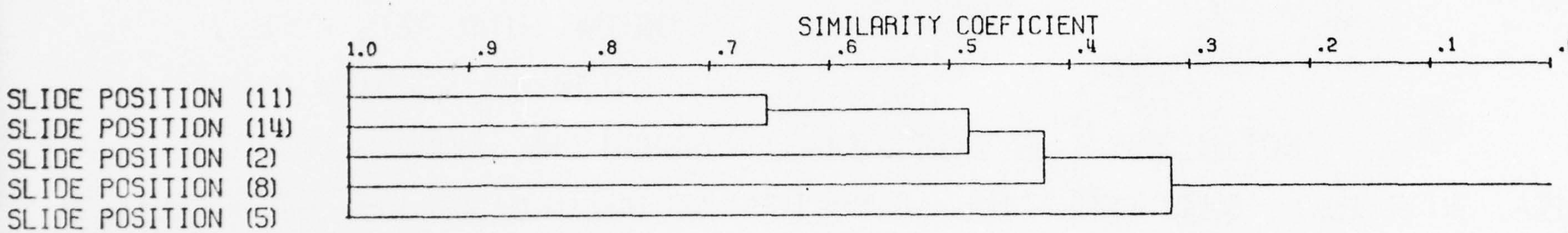
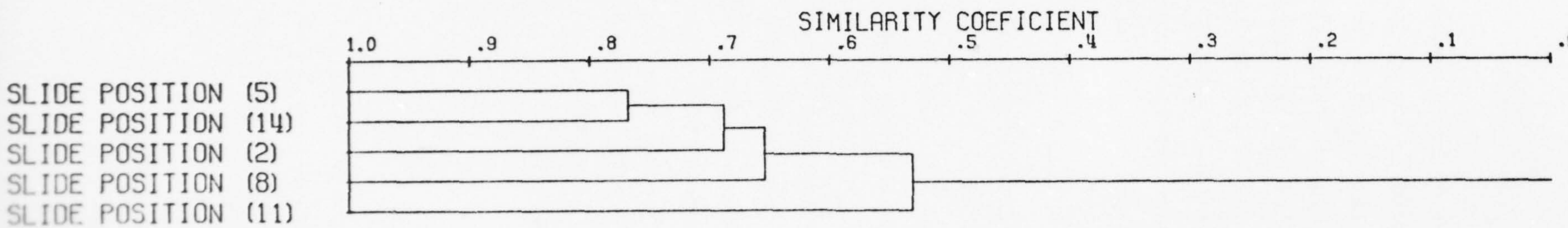


Figure 19. STATION B8-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



AD-A036 776 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITI--ETC(U)
NOV 76 S L SANOCKI, P B SIMON, R L WEITZEL DAMD17-75-C-5046

UNCLASSIFIED NL

3 OF 5
AD
A036776

3677

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0 4.5 5.0 5.6 6.3

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

1.03 (Table 60) but would be somewhat lower at 0.56 if the most different replicate was ignored. This difference of 0.47 is very significant and the adjusted diversity, 0.56 is most likely more indicative of the diatom diversity at this station. (Figure 20)

10) At station S2 the diatom species distribution of the five replicates was similar above the 45 percent level (Figure 21), with three replicates being similar above the 60 percent level. Calculating the mean diatom species diversity for the three replicates as mentioned above, the value remains the same, 2.30, as when calculated using the five replicate samples.

Through the application of species diversity and coefficient of similarity to the replicate samples at every station, a better description of the diatom likeness, as shown by the coefficient of similarity, indicated whether or not a sufficient sample was taken to adequately describe the existing community. It was shown that most often one of the five replicate samples was quite different from the remaining samples and the presence or absence of its species data had little effect on the estimation of diatom community structure, i.e. species diversity. Thus, the inclusion of all replicate samples on a combined basis at each station provided a broader species complex from which station-to-station comparisons were made. This approach included the occurrence of many rare and uncommon species but did not significantly alter the calculated mean diatom species diversity at the respective stations.

Mean diatom species diversity of periphyton collected from artificial substrates decreased slightly when moving downstream from station B1 to B2 which then increased sharply at station B3. Downstream at stations B4 and B5, diversity decreased with station B5 being at a similar level to station B2 (Table 60; Figure 11). Species diversity then increased significantly at stations B6 and B7 with a slight decrease at station B8. Species evenness (Table 61; Figure 11) showed a parallel trend with

Figure 20. STATION S1-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

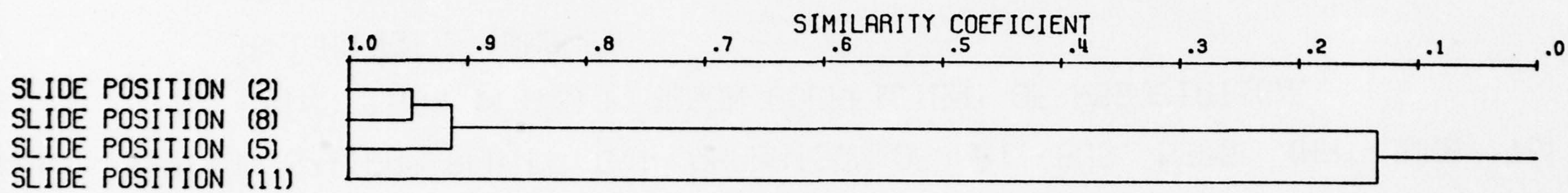
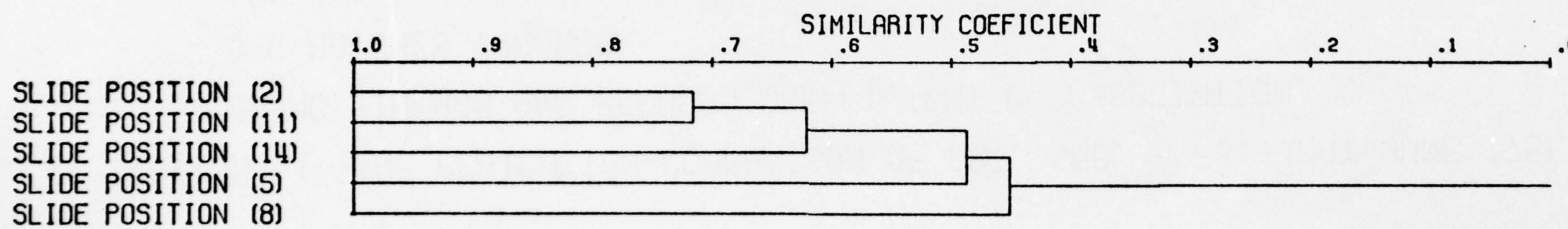


Figure 21. STATION S2-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT



species diversity, but decreases and increases were more gradual.

Species diversity differed considerably between the two Spring Creek staions. A large increase of about 3.0 occurred between station S1 and station S2 (Table 60; Figure 11). Species evenness paralleled species diversity (Table 61; Figure 11).

Diatom species data from replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in four stations (S1, S2, B1, and B8) being grouped due to the relatively high similarity between them. Station S2 was similar to station B8 (recovery zone) and station B1 (reference station of Brush Creek) at the 38 percent and 36 percent levels, respectively (Table 62; Figure 22). It was less similar to station S1 (30 percent). The Spring Creek station S1 was more similar to station B8 (33 percent) than to station S2 (30 percent). Station B1 was less similar to station B8 (29 percent) and station S1 (27 percent) than to station S2. Three of these stations, i.e. S2, B1, S1, were expected to be similar based on the fact that they were chosen as reference stations, i.e. no industrial effluents to affect the diatom population. The fourth station, B8 was selected to indicate the downstream conditions and possible recovery and its similarity with the upstream reference station is encouraging.

Among the remaining stations, B3, B4 and B7 were similar at the 40 percent level (Figure 22). These three stations showed the highest species diversity of the Brush Creek stations sampled. The B2, B5 and B6 stations had diatom species associations similar at the 55 percent level (Figure 22). These stations were also alike in that they had lower species diversities than the other stations on Brush Creek. Both groups of three stations i.e. B3, B4, B7, vs. B2, B5, B6 were similar above the 25 percent level while the reference and recovery stations

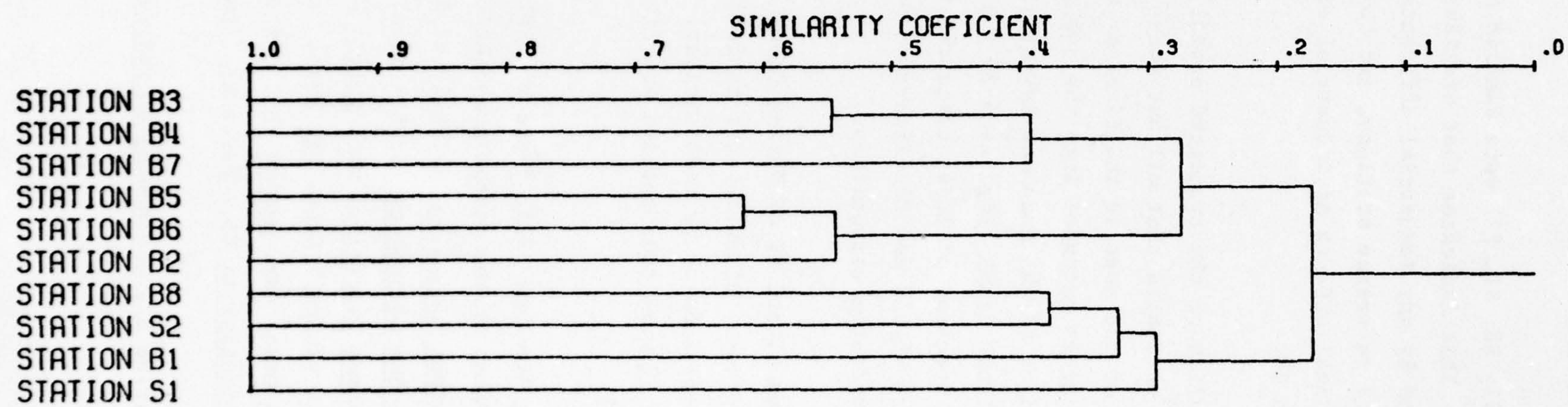
Table 62. COEFFICIENT OF ASSOCIATION COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED ARTIFICIAL SUBSTRATE REPLICATES AT EACH STATION.

IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS

BURLINGTON, IOWA MAY-JUNE 1975

	Brush Creek								Spring Creek	
Stations	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
B1	1.000									
B2	0.223	1.000								
B3	0.337	0.240	1.000							
B4	0.155	0.160	0.546	1.000						
B5	0.200	0.567	0.248	0.181	1.000					
B6	0.230	0.520	0.350	0.274	0.616	1.000				
B7	0.250	0.272	0.459	0.324	0.325	0.399	1.000			
B8	0.285	0.132	0.336	0.210	0.131	0.221	0.331	1.000		
S1	0.274	0.062	0.243	0.176	0.059	0.139	0.154	0.330	1.000	
S2	0.363	0.048	0.353	0.277	0.064	0.150	0.181	0.377	0.301	1.000

Figure 22.
IAAP PERIPHYTON-ART. SUB. COMPARISONS-COMB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



(i.e. B1, B8, S1, S2) were similar to the others at only the 16 percent level. This indicates that stations B1, S1, and S2 were probably not affected by any industrial effluents or detrimental runoff and served as adequate reference stations, and that Brush Creek had recovered from the pollutional effects of industrial effluents by the time it reached station B8.

Application of the truncated normal curve to the Brush Creek periphyton data [28] revealed that all but three stations (B3, B4, and B5) had the height of the mode in the first or second interval. The length of these curves extended into the twelfth interval. At station B1 (Figure 23) the height of the mode was low at about four species. Stations B2 through B8 of Brush Creek (Figures 24-30) had their mode height between eight and eleven species, at least twice the height of the mode at Station B1. Stations B6, B7 and B8 (Figure 28-30) had curves representative of very diverse diatom communities.

Stations S1 and S2 of Spring Creek had curves more like station B1 of Brush Creek. Likewise, the coefficient of similarity (Figure 22) showed these stations to be most similar. The height of the mode for stations S1 and S2 were four species and five species, respectively (Figures 31 and 32).

During May-June 1975, there were six species of diatoms which comprised 83 percent of the diatom association at station B1. These were Gomphonema bohemicum Reichelt et Fricke var. bohemicum (31.2 percent), Achnanthes lanceolata (Breb.) Grun. var. lanceolata (19.0 percent), Gomphonema intricatum var. pumila Grun. (13.1 percent), Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh. var. curvata (8.8 percent), Navicula minima Grun. var. minima (6.1 percent) and Achnanthes minutissima Kuetz. var. minutissima (5.2 percent) (Appendix X).

At station B2, Gomphonema bohemicum Reichelt et. Fricke var. bohemicum

FIGURE 23. Distribution of Diatom Community Collected on Artificial Substrates. Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May–June 1975

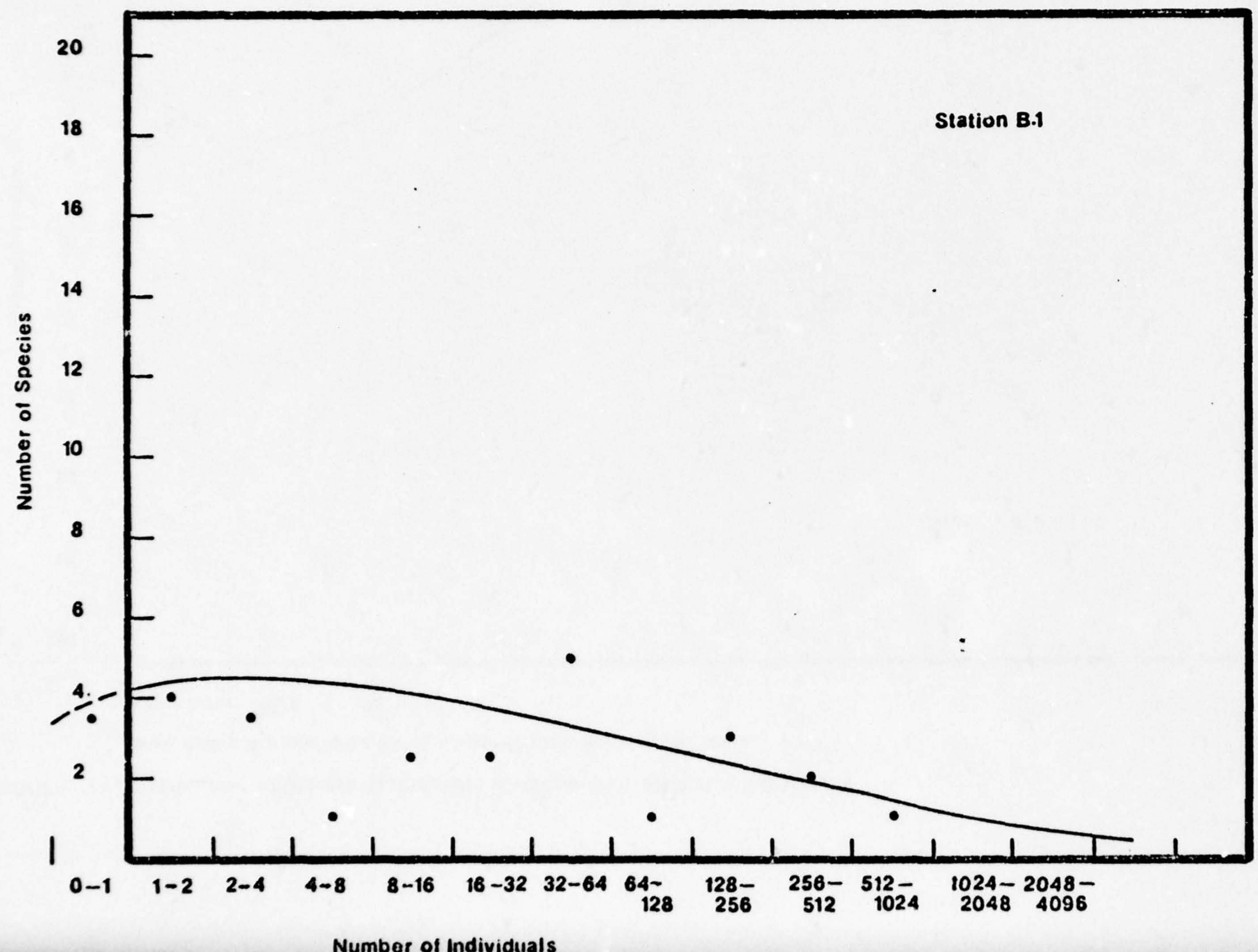


FIGURE 24. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.
May—June 1975

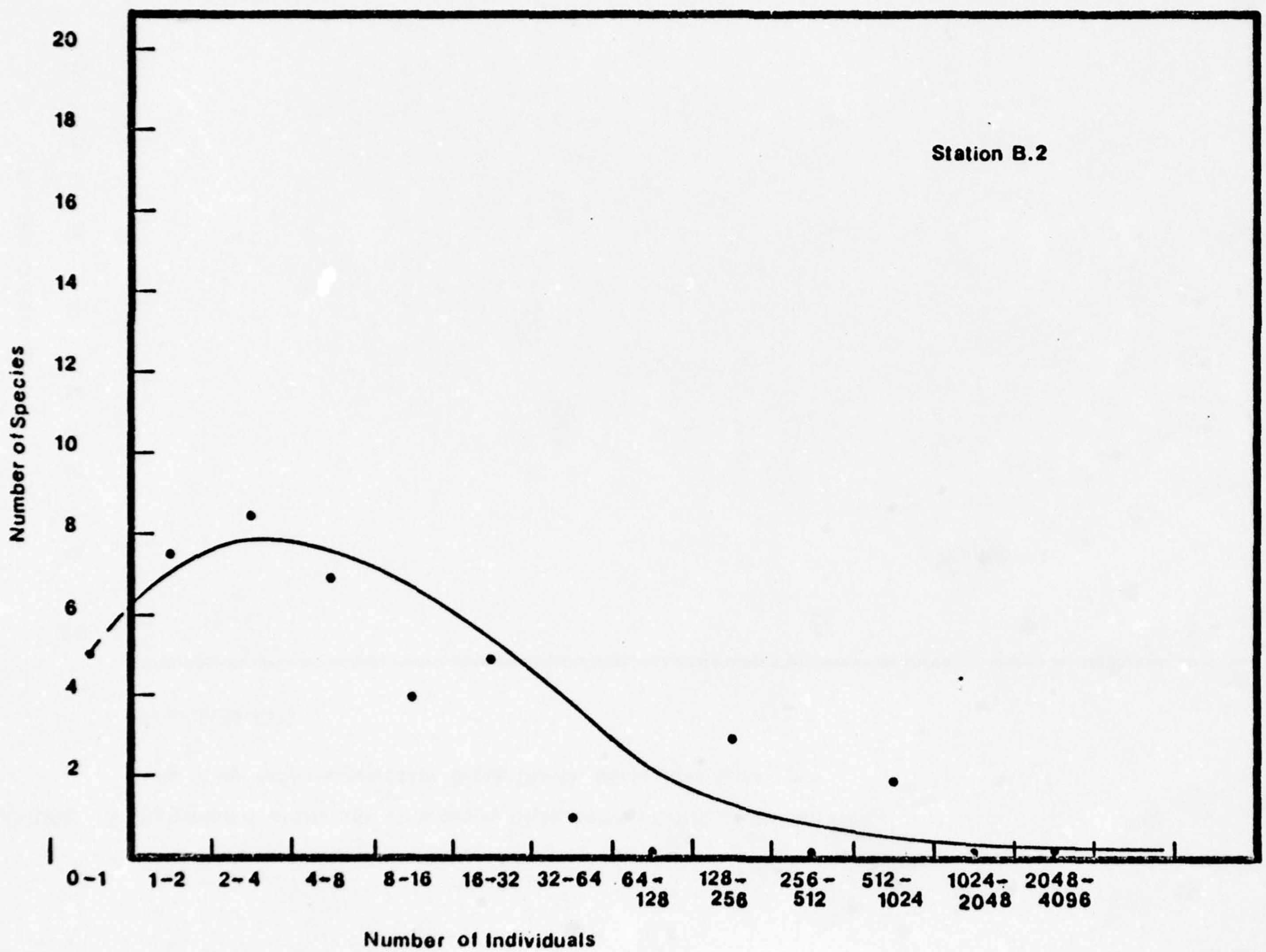


FIGURE 25. Distribution of Diatom Community Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May–June 1975

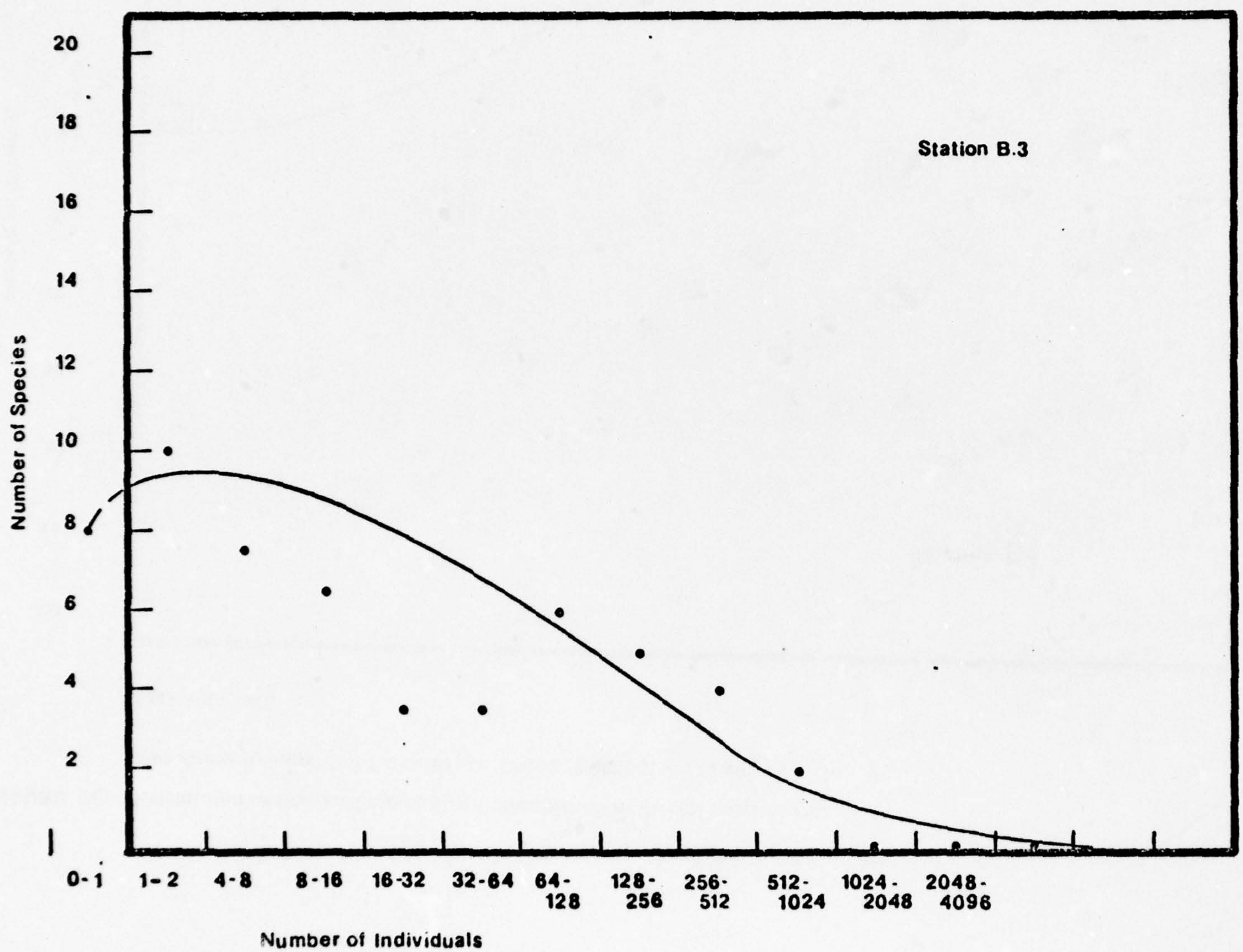


FIGURE 26. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May-June 1975

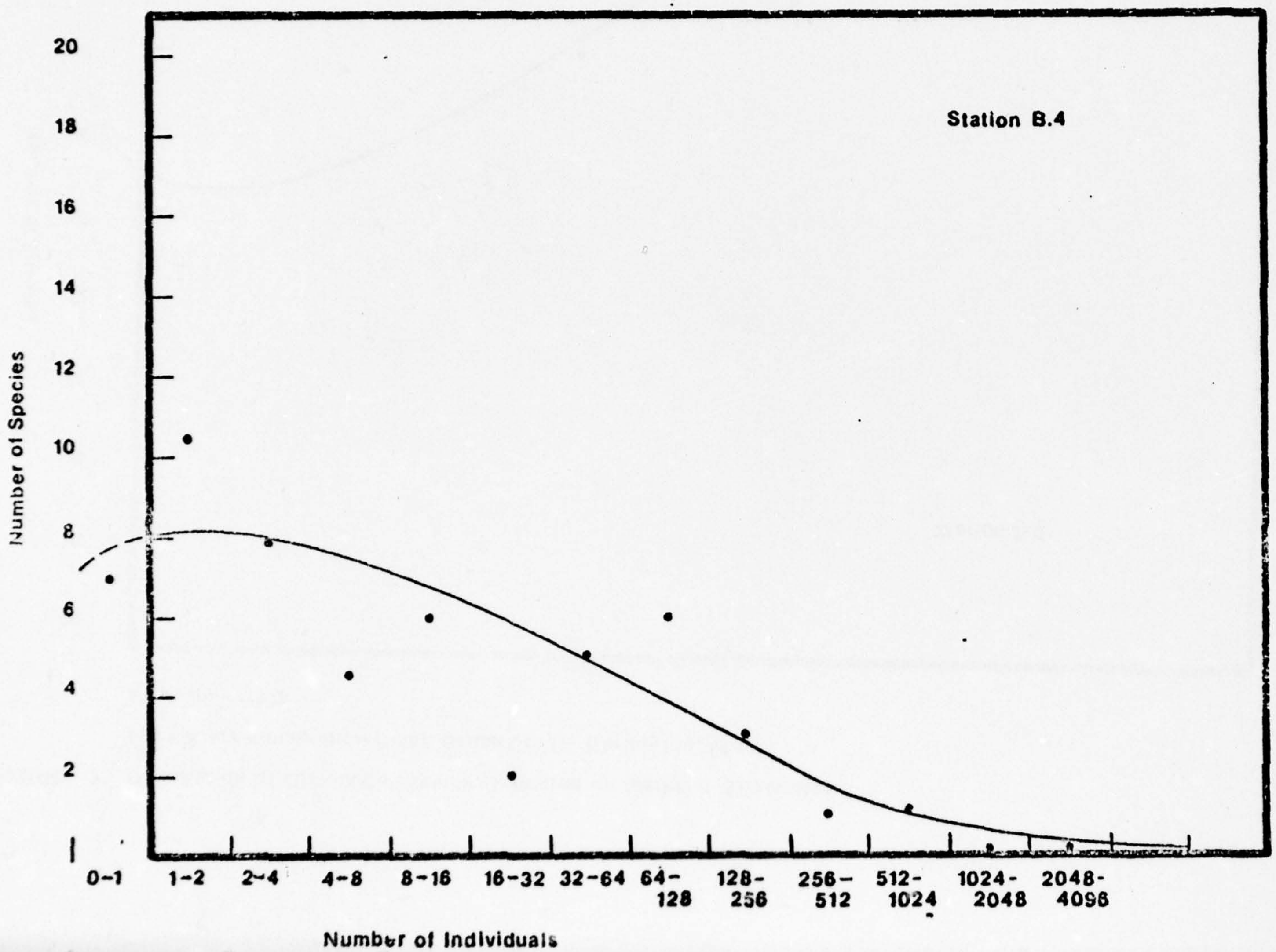


FIGURE 27. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May–June 1975

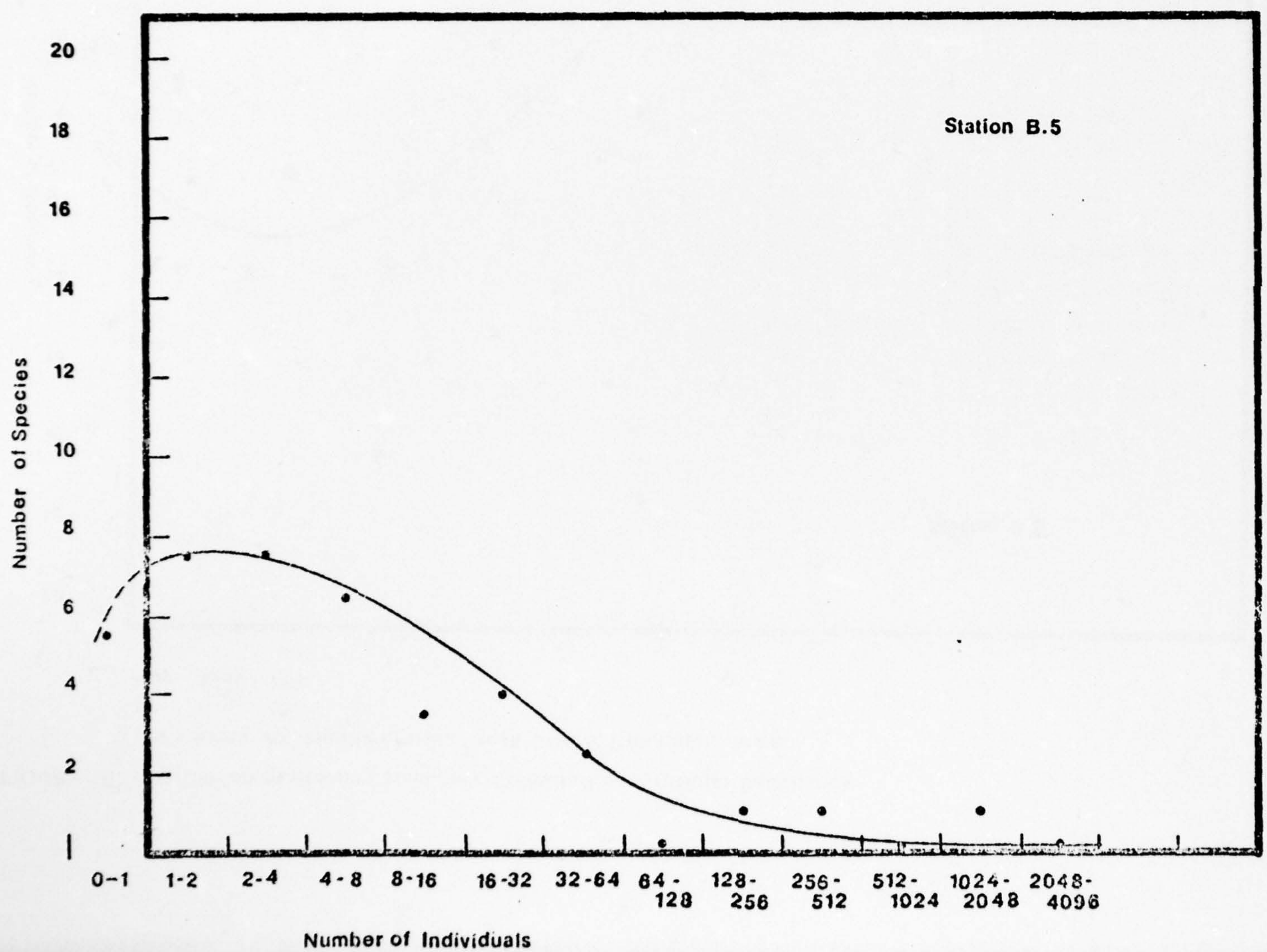


FIGURE 28. Distribution of Diatom Community Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May—June 1975

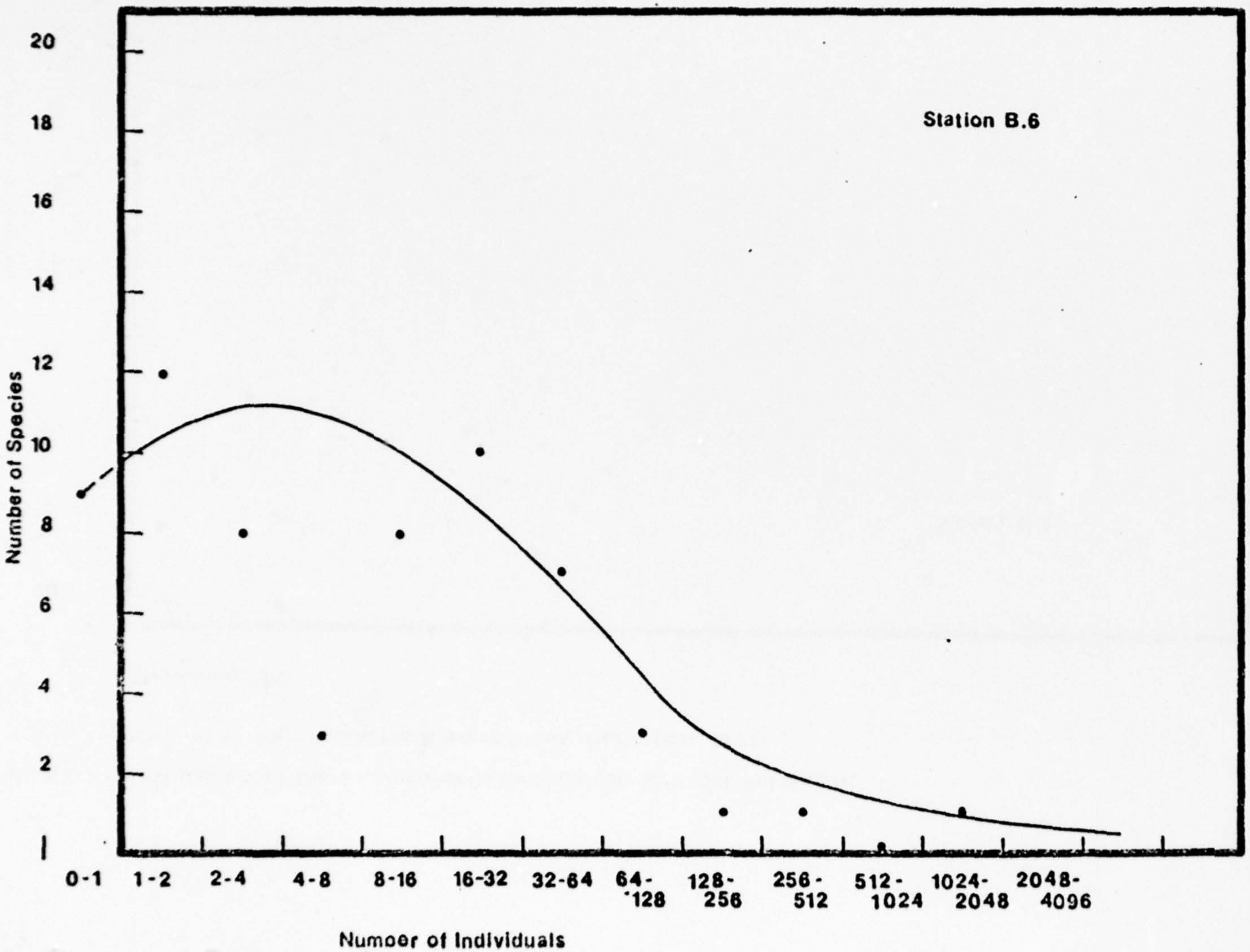


FIGURE 29. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May-June 1975

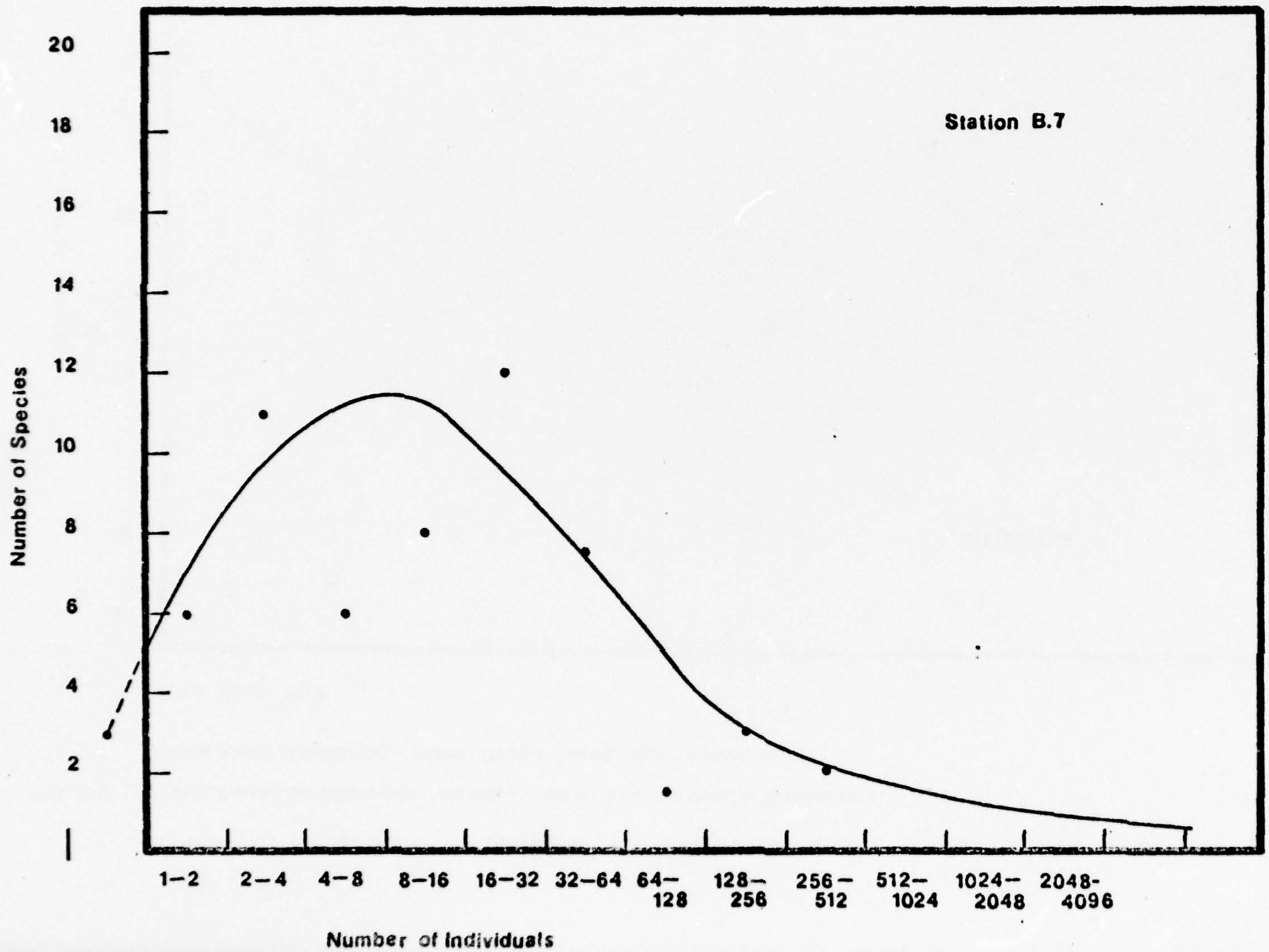


FIGURE 30. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

May-June 1975

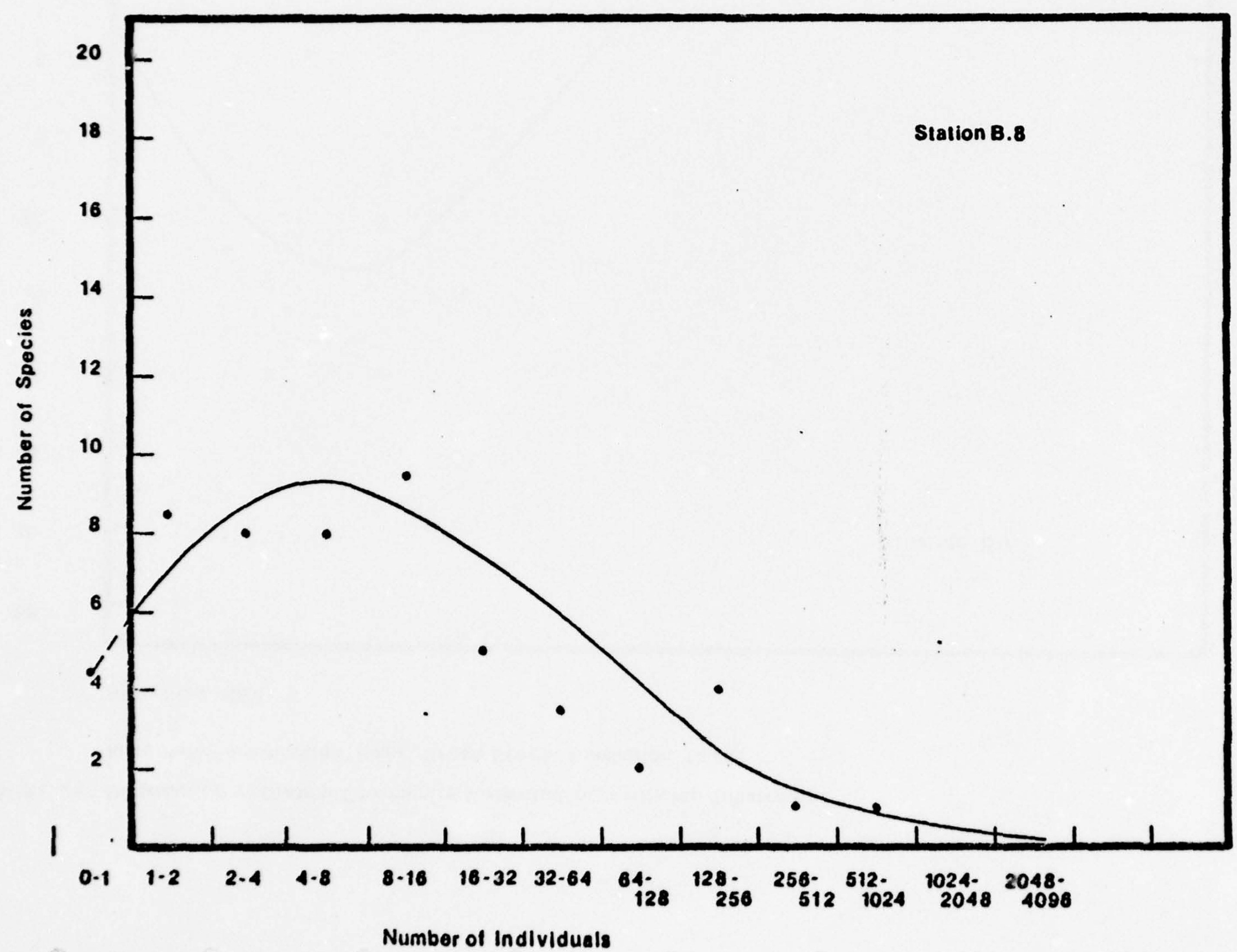


FIGURE 31. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Spring Creek, Burlington, Iowa.

May–June 1975

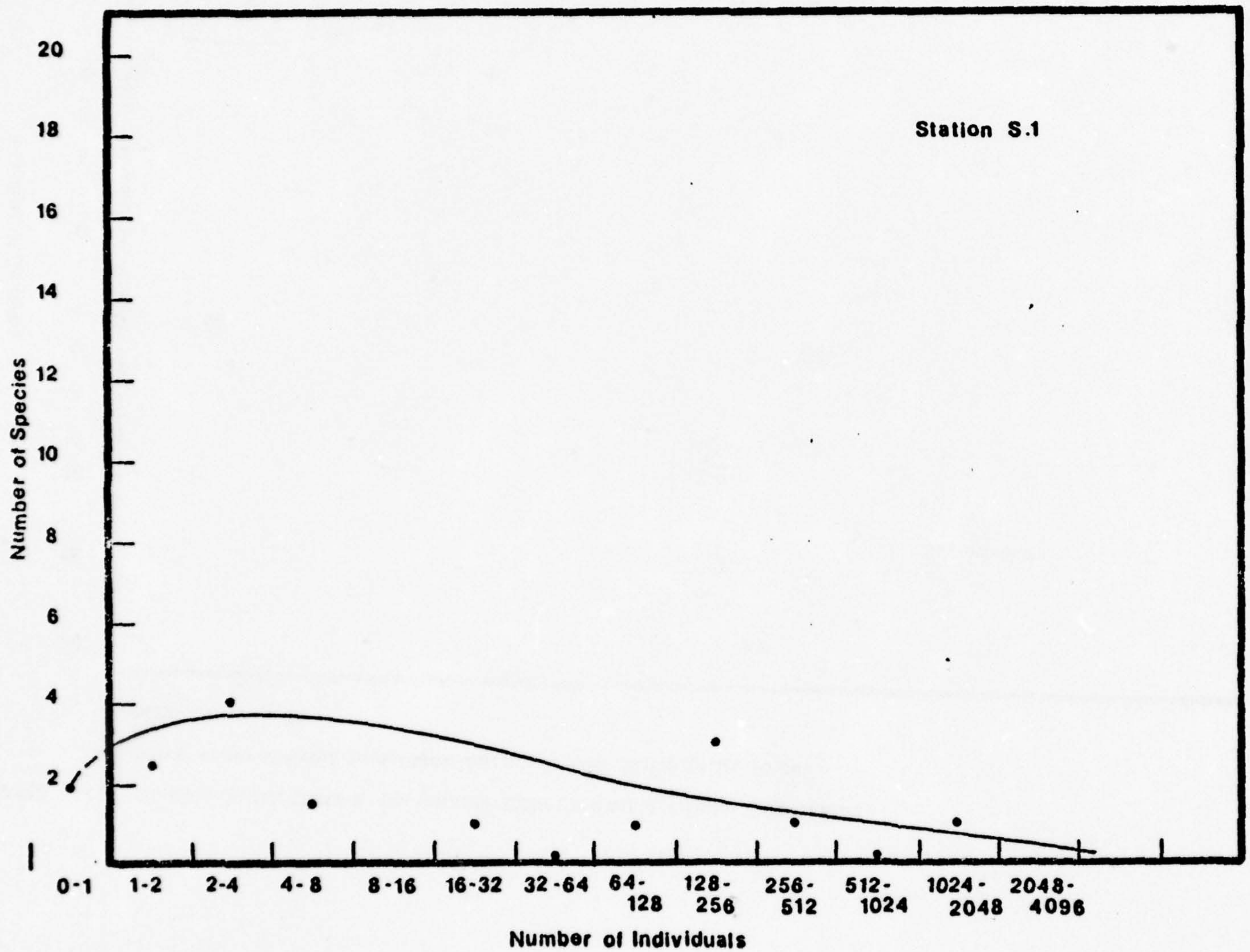
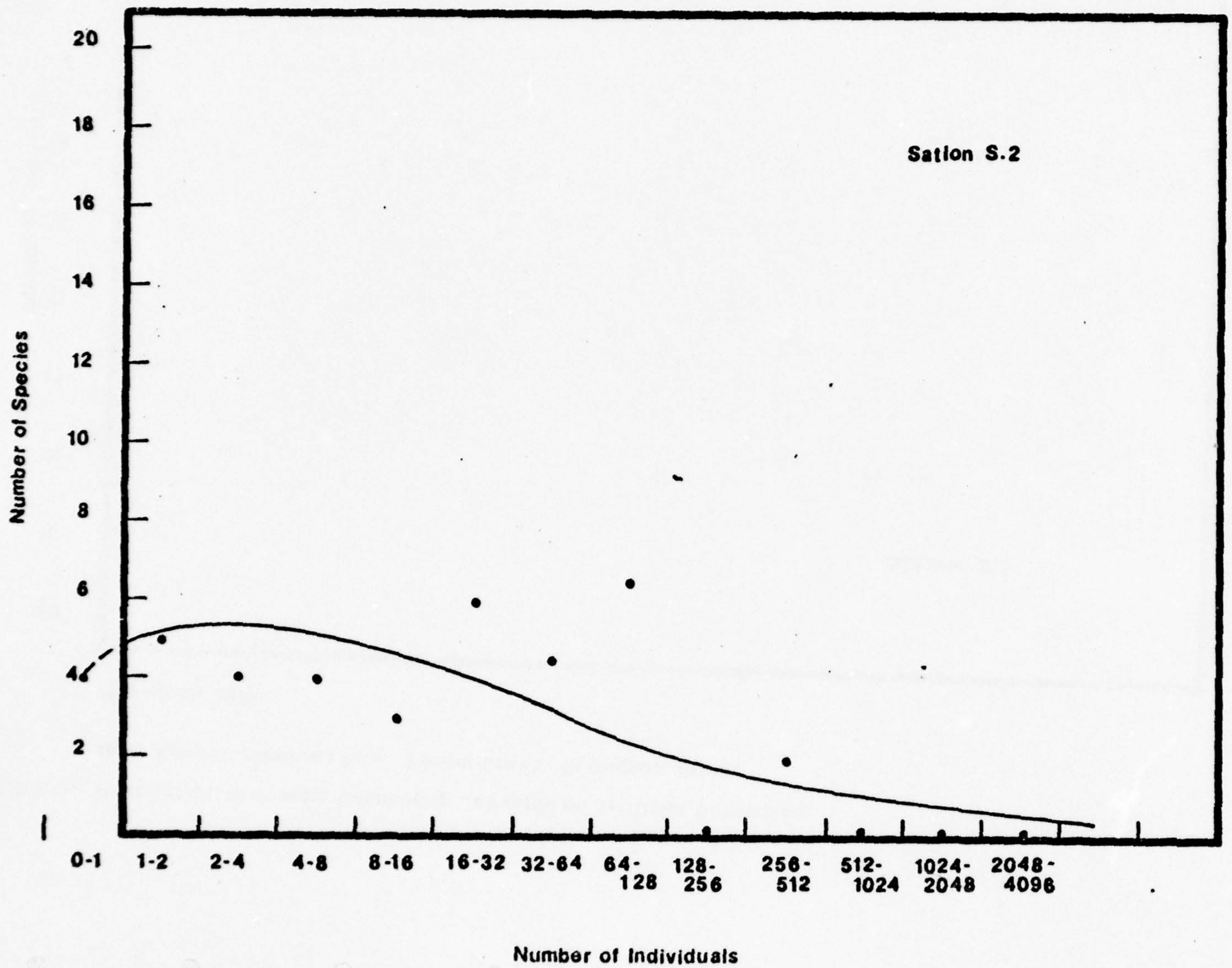


FIGURE 32. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Spring Creek, Burlington, Iowa.
May—June 1975



decreased below one percent, while Achnanthes lanceolata var. dubia Grun. increased to 25.8 percent and was common. Achnanthes lanceolata (Breb.) Grun. var. lanceolata was dominant increasing in occurrence from 19.0 percent to 36.2 percent. Three other species were uncommon (occasional) above the five percent level. These species were Achnanthes minutissima Kuetz.var. minutissima (9.8 percent), an increase from station B1, Surirella ovalis Breb. var. ovalis (9.5 percent) and Navicula pseudoatomus Lund var. pseudoatomus (6.6 percent) (Appendix X). Thus five species comprised 78 percent of the diatom dominance at station B2.

Seven species were present at station B3, comprising 68 percent of the total diatom community structure. Gomphonema bohemicum Reichelt et Fricke var. bohemicum increased from below one percent to 18.7 percent while Achnanthes lanceolata (Breb.) Grun. var. lanceolata increased from 36.2 percent to 9.2 percent. Surirella ovalis Breb. var. ovalis decreased slightly to 6.7 percent. Four new species appeared among the dominants with Nitzschia fonticola Grun. var. fonticola being co-dominant to Gomphonema bohemicum Reichelt et Fricke var. bohemicum at 10.1 percent. The other three common species in order of decreasing dominance were Gomphonema parvulum Kuetz. var. parvulum, G. angustatum (Kuetz.) Rabh. var. angustatum and Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh. var. curvata (Appendix X).

Gomphonema parvulum Kuetz. var. parvulum (26.7 percent) was the most dominant species of the five that comprised 62 percent of the diatom population at station B4. The only species not among the dominants at this station, but which were common at B3 were Anchnanthes lanceolata (Breb.) Grun. var. lanceolata and Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh. var. curvata. Nitzschia fonticola Grun. var. fonticola and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum increased while Gomphonema bohemicum Reichelt et. Fricke var. bohemicum and Surirella ovalis Breb. var. ovalis decreased in occurrence.

At station B5 three species comprised 70 percent of the diatom population, with Achnanthes lanceolata (Breb.) Grun. var. lanceolata increasing greatly from 9.2 percent at B3 to 52.6 percent. Achnanthes lanceolata var. dubia and Surirella ovalis Breb. var. ovalis were present at 12.2 percent and 5.4 percent respectively.

Station B6 also had three diatom species together comprising 64 percent of the diatom association. Gomphonema parvulum Kuetz. var. parvulum was common at 9.2 percent. Achnanthes lanceolata (Breb.) Grun. var.

lanceolata decreased in occurrence by 10 percent but was still dominant while Achnanthes lanceolata var. dubia decreased only 0.3 percent.

A new dominant species, Nitzschia palea (Kuetz.) W. Sm. var. palea (17 percent) appeared at station B7. Four other species, Achnanthes lanceolata (Breb.) Grun. var. lanceolata (16.4 percent), Nitzschia fonticola Grun. var. fonticola (8.0 percent), Gomphonema parvulum Kuetz. var. parvulum (7.5 percent) and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (5.9 percent) together comprised 38 percent of the diatom population at this station.

Station B8 had a very different population dominance. Cocconeis pediculus Ehr. var. pediculus was the most dominant (32.6 percent) of six species which together comprised 73 percent of the population at this station. Gomphonema intricatum var. pumila Grun., which was common at only the B1 station, recurred at B8 at the 12.5 percent level. Other species present and occurring over the 5 percent level (common) in ranking order were Cocconeis placentula var. euglypta (Ehr.) Cl., Achnanthes lanceolata (Breb.) Grun. var. lanceolata, Gomphonema parvulum Kuetz. var. parvulum and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (Appendix X).

Spring Creek species dominance was much the same as Brush Creek but at different percentage levels. Station S1 had six species which comprised 98 percent of the diatom association. Cocconeis placentula var. euglypta (Ehr.) Cl. was the most dominant (57.9 percent) with Gomphonema intricatum var. pumila Grun. (10.4 percent), G. bohemicum Reichelt et Fricke var. bohemicum (9.0 percent), Gomphonema parvulum Kuetz. var. parvulum (7.6 percent), Achnanthes lanceolata (Breb.) Grun. var. lanceolata (6.7 percent) and Rhoichosphenia curvata (Kuetz.) Grun. ex Rabh. (6.5 percent) following.

At station S2, 61 percent of the diatom population was comprised of four species. Twenty-seven percent of the diatom association was Rhoicosphenia

curvata (Kuetz.) Grun. var. curvata, compared to 6.5 percent at station S1. Gomphonema bohemicum Reichelt et Fricke var. bohemicum, Gomphonema intricatum var. pumila Grun. and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum occurred next in decreasing order.

Differences in diatom community structure and similarity which occurred between the sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare species, each occurring at a level of between five and one percent or less than one percent, respectively. To summarize Appendix X , total number of taxa per station increased moving downstream. The three most upstream stations averaged a total taxa of 43, while the mid-stream stations averaged 56 taxa. The two downstream stations, B7 and B8, averaged 60 taxa. Stations S1 and S2 of Spring Creek had 17 taxa and 40 taxa respectively.

Occurrence of non-diatom algae on artificial substrates (May-June) - Non-diatom algae comprised a large percentage of the periphyton community in terms of species occurrence. This occurrence was related only as percent dominance and not as numbers per unit area nor as biomass per unit area. At station B1 Oscillatoria limnetica Lemm. was dominant at 35 percent. The pennate diatoms and a blue-green alga, Phormidium mucicola Naumann & Huber-Pestalozzi, were present at 24 percent and 11 percent, respectively. Six other non-diatom species occurred under the six percent level (Appendix XI).

Unlike station B1, the pennate diatoms (73 percent) were dominant at station B2. The most dominant non-diatom specie was Protoderma viride Kuetz. at 7.6 percent occurrence of 10 other non-diatom species were under five percent.

Station B3 was dominanted by Protoderma viride Kuetz. which increased from 7.6 percent at station B2 to 42.1 percent. The pennate diatoms were

present at a level of 31 percent. The remaining seven species occurred at a level of less than nine percent.

A member of the Cyanophyta, Chroococcus dispersus (Keissl.) Lemm. (48 percent), was dominant at station B4 while the pennate diatoms occurred at the 29 percent level. Six species of non-diatom algae comprised the other 23 percent of the population.

Chroococcus dispersus (Keissl.) Lemm. increased greatly from station B4 (48 percent) to station B5 (71 percent). The pennate diatoms were only at the 14 percent level of dominance. All other species occurred at less than the 10 percent level.

Protoderma viride Kuetz. recurred at station B6, increasing to 21 percent from 7.6 percent at station B3. The pennate diatoms as a group, and Chamaesiphon incrustans Grun. each were present at 20 percent. Two other species were common over the 10 percent level and the remaining five species found at this station occurred under six percent.

At station B7, Protoderma viride Kuetz. remained at the 20 percent level of occurrance. Occurring at a higher dominance level were the pennate diatoms (25 percent) and Chamaesiphon incrustans Grun. (24 percent). Characium ambiguum Hermann was present above 10 percent.

Again, at station B8, Protoderma viride Kuetz. was the most dominant non-diatom alga (22 percent). The pennate diatoms doubled in dominance from 25 percent to 50 percent. Chroococcus dispersus (Keissl.) Lemm. and Chamaesiphon incrustans Grun. were common at exactly 10 percent. All other species were present under five percent.

Both Spring Creek stations, S1 and S2, showed the pennate diatoms to be dominant at 53 percent and 44 percent, respectively (Appendix XI). Co-dominant at both stations was Protoderma viride Kuetz. occurring at

20 percent at station S1 and 15 percent at station S2. Common at both stations was Chamaesiphon incrustans Grun. These two stations showed a similar dominance of non-diatom species to the downstream stations of Brush Creek (stations B6, B7, and B8).

The application of a simplified species richness formula to these data indicated little variation in periphyton community structure. The formula used was S-1/lnN where: S = the number of species, and N = the number of individuals counted [23]. Species richness was similar at the most upstream stations (B1, B2 and B3) with a slight decrease occurring in the central area (stations B4 and B5) of Brush Creek. At stations B6 and B7 species richness increased again, however, at station B8 it dropped sharply to a low level of 0.84 (Table 63). The pennate diatoms were most dominant at station B8. The low species richness (0.84) at this station is probably associated with the large mats of Cladophora that covered the periphyton samplers during the June collection period. From station S1 to station S2 of Spring Creek an increase was seen in species richness. Observed variations were the result of the loss of uncommon species between these stations and the increase in the number of individuals, especially the pennate diatoms.

Table 63. SPECIES RICHNESS OF NON-DIATOM ALGAE BASED ON THREE COMBINED ARTIFICIAL SUBSTRATE REPLICATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK, BURLINGTON, IOWA. MAY-JUNE, 1975

Station	Species Richness	Station	Species Richness
B1	1.40	B7	1.61.
B2	1.41	B8	0.84
B3	1.33	S1	1.30
B4	1.20	S2	1.70
B5	1.23		
B6	1.52		

Diatom dominance on natural substrates (May-June) - Samples collected from natural substrates included growths on wood, rock, and sediment surfaces. Tables 64 and 65 show the values of species diversity and evenness for each substrate, respectively, as well as the mean and standard deviation for these values. Diversity based on combined species data from the three substrate types is also included in Table 64. The combined species diversity is more representative of the periphyton community occurring at the different stations because these are not true replicate samples since they are from different substrate types.

Using the combined species diversity values the following were noted:

1) Two natural substrates, wood and sediment showed a high species diversity at station B1 (Table 64). Combined species diversity was also very high (2.90).
2) At station B2, individual diversity for each substrate was 2.69 and 2.54 for wood and sediment, respectively. Mean species diversity was 2.61 while combined species diversity was calculated at 2.73.
3) Species diversity for the three natural substrate samples collected from station B3 showed values between 2.20 and 2.50 (Table 64). The combined species diversity was 2.33.
4) The wood and sediment samples at station B4 had lower values for species diversity. A combined species diversity of 2.23 was observed at this station.
5) Species diversity for the three natural substrates was very close at station B5. Periphyton species diversity for wood was 2.23, rock was 2.12 and sediment was 2.24, with a combined species diversity of 2.20.
6) Species diversity of the rock substrate at station B6 was low (1.93) compared to the other stations of Brush Creek. On wood and sediment the species diversity was 2.97 and 2.70, respectively, Combined species diversity was 2.82.

Table 64. SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. MAY - JUNE, 1975.

	Brush Creek								Spring Creek	
Sample Type	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Wood	2.61	2.69	2.43	2.03	2.23	2.97	2.40	2.37	1.61	2.28
Rock	*	*	2.36	2.42	2.12	1.93	2.85	2.20	1.93	2.57
Sediment	2.57	2.54	2.21	*	2.24	2.70	2.92	2.52	2.80	2.92
$\overline{X}$	2.60	2.61	2.33	2.23	2.20	2.53	2.72	2.36	2.11	2.60
s^2	0.001	0.01	0.01	0.08	0.004	2.30	0.08	0.02	0.40	0.10
s	0.03	0.11	0.12	0.28	0.07	0.54	0.30	0.16	0.62	0.32
Combined Diversity	2.90	2.73	2.63	2.68	2.67	2.82	3.12	2.68	2.56	2.87

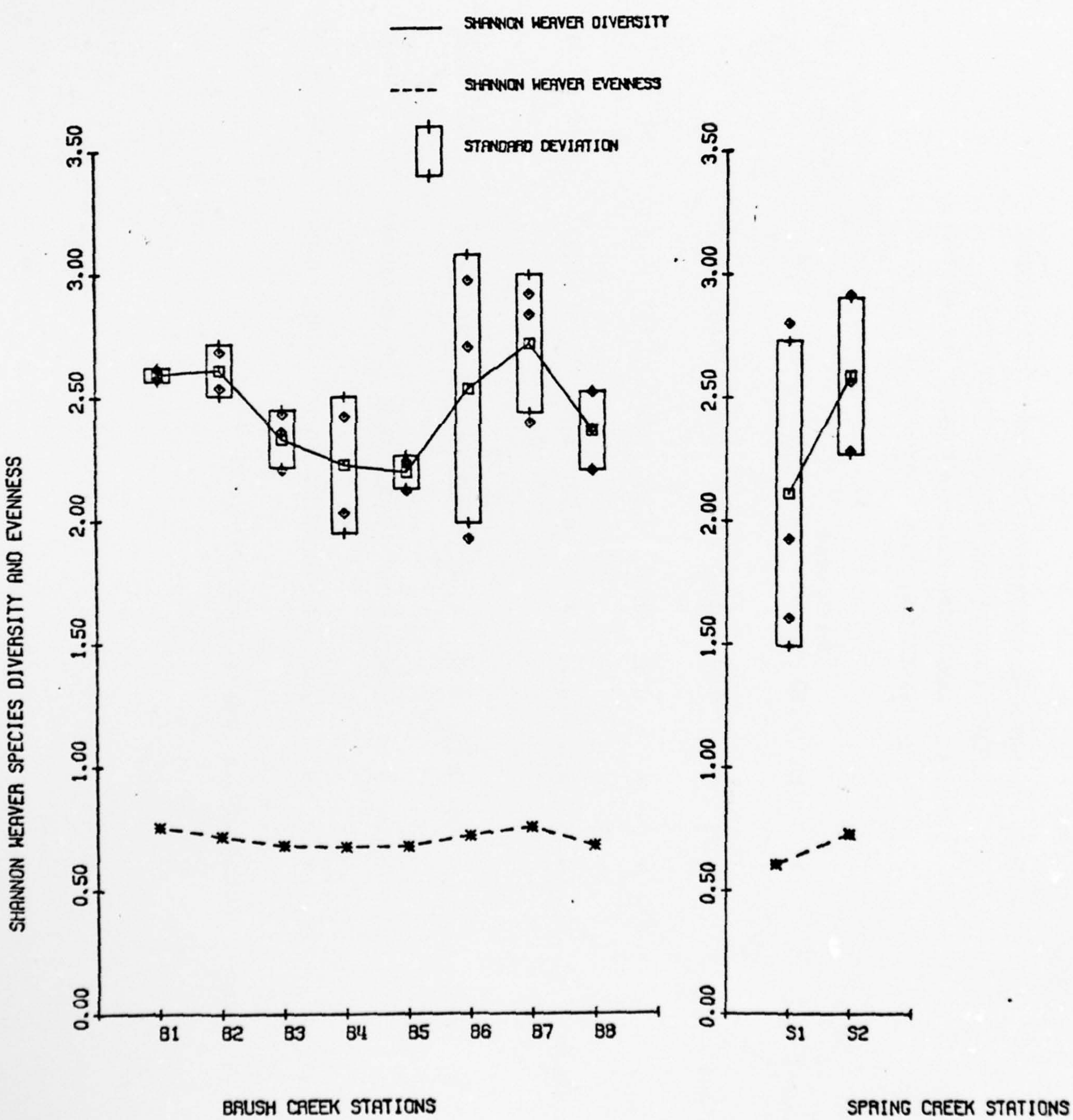
*Due to substrate limitations, no samples were collected.

Table 65 . SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. MAY-JUNE 1975

	Brush Creek								Spring Creek	
Sample Type	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Wood	0.76	0.72	0.75	0.68	0.67	0.81	0.68	0.67	0.49	0.63
Rock	*	*	0.65	0.68	0.65	0.60	0.79	0.65	0.57	0.75
Sediment	0.75	0.71	0.65	*	0.72	0.76	0.79	0.73	0.76	0.81
$\overline{X}$	0.756	0.719	0.68	0.68	0.68	0.72	0.76	0.68	0.607	0.73
S^2	0.00	0.00	0.003	0.00	0.001	0.01	0.004	0.002	0.02	0.01
S	0.01	0.01	0.05	0.002	0.03	0.11	0.06	0.04	0.14	0.09

*Due to substrate limitations, no samples were collected.

Figure 33. IAAP PERIPHTON-DIVERSITY FOR NAT. SUB. (JUNE 75)



7) At station B7, combined species diversity was much higher (3.12) than the mean species diversity (2.72). The sample from the sediment substrate had a species diversity of 2.92 while the wood and rock substrates showed species diversities of 2.40 and 2.84, respectively.
8) Species diversity for the three natural substrate samples collected from station B8 showed values between 2.20 and 2.50. The combined species diversity was 2.68.
9) Station S1 of Spring Creek had very low species diversities for the individual samples (Table 64). The mean species diversity was low (2.11) while the combined species diversity was much higher (2.56).
10) At station S2, individual species diversity for each substrate ranged from 2.30 to 2.90. The combined species diversity was 2.87 at this station.

Mean diatom species diversity of periphyton collected from natural substrates showed a very small increase between station B1 (2.59) and station B2 (2.61) (Table 64 ; Figure 33). A decrease continued through stations B3, B4 and B5, with station B5 having the lowest values (2.20). An increase then occurred from station B5 through station B7 which had the highest diversity (2.72) value for any of the Brush Creek stations. A sharp decrease was then seen between station B7 and station B8 (2.72 to 2.37). At Spring Creek, an increase occurred between station S1 (2.11) and station S2 (2.60).

The combined species diversity trend was similar to the mean species diversity with values a few points higher and some small variations between the stations. A sharp decrease occurred between stations B1, B2 and B3 with station B4 and station B5 having diversity values that were similar to station B3. From station B5 a sharp increase occurred to station B7 with a sharp decrease then to station B8. The Spring Creek stations, S1 and S2, showed the same increase between stations.

Species evenness (Table 65 ; Figure 33) showed a parallel trend with species diversity.

Diatom species data from the three natural substrates were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in the six most upstream stations (B1, B2, B3, B4, B5, and B6) being grouped due to the relatively high similarity between them. Each station was similar to the other five stations above the 50 percent level. Stations B4 and B5 were the most similar (70 percent) with station B1 being similar to both these stations at 65 percent. Stations B2, B3 and B6 were similar to the other three stations at 60 percent, 63 percent and 55 percent levels, respectively (Table 66; Figure 34).

One Brush Creek station (B8) and two Spring Creek stations (S1 and S2) were very similar. These stations represent the recovery zone of Brush Creek and the reference stations of Spring Creek. Station S1 and station S2 were similar at 63 percent which was expected based on their occurrence and close proximity on the same stream with no industrial effluent present to affect the diatom population. Station B8 was similar to these two stations at 57 percent.

Both groups of stations (B1, B2, B3, B4, B5, B6 and B8, S1, S2) were similar at 55 percent. Station B7 of Brush Creek, which is just below the IAAP domestic sewage treatment plant, was the least similar to any of the other sampling stations. It was similar to all stations at the 50 percent level. Station B7 was similar to its adjacent stations B6 and B8 at 52 percent (Table 66).

Percent dominance of the diatom species occurring on natural substrates was calculated from the species list in Appendix XII. During May-June 1975, there were five species of diatoms which comprised 57 percent of the

Table66 . COEFFICIENT OF ASSOCIATION COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATES AT EACH STATION.

IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS BURLINGTON, IOWA. JUNE 1975

	Brush Creek								Spring Creek	
Stations	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
B1	1.000									
B2	0.600	1.000								
B3	0.559	0.578	1.000							
B4	0.631	0.606	0.641	1.000						
B5	0.663	0.591	0.630	0.698	1.000					
B6	0.544	0.525	0.572	0.601	0.651	1.000				
B7	0.496	0.505	0.515	0.532	0.550	0.519	1.000			
B8	0.511	0.483	0.558	0.561	0.620	0.537	0.520	1.000		
S1	0.562	0.542	0.616	0.611	0.611	0.559	0.472	0.577	1.000	
S2	0.557	0.506	0.535	0.616	0.635	0.532	0.449	0.566	0.632	1.000

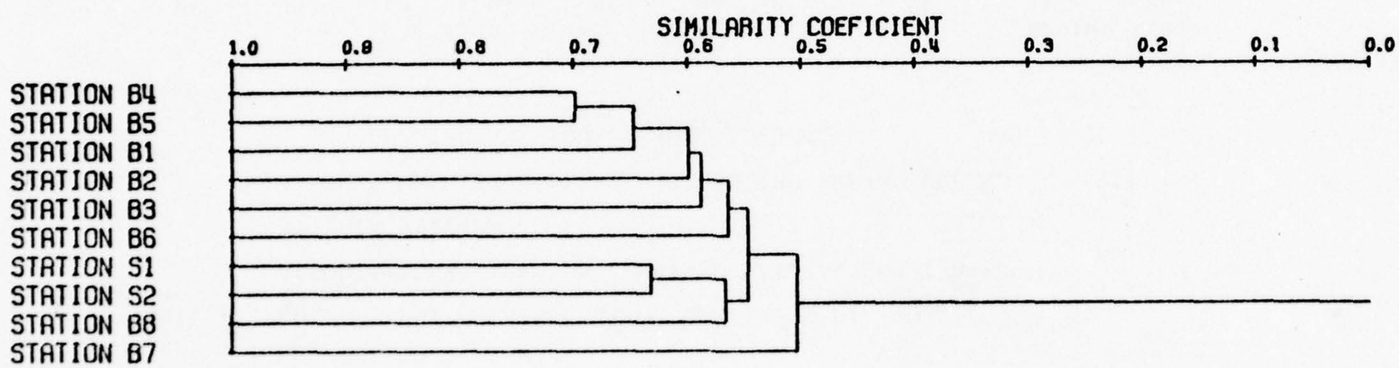


Figure 34. IAAP PERIPHYTON-STATION COMPARISON OF NATURAL SUBSTRATES (JUNE 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

diatom association at station B1. These were Surirella ovalis Breb. var. ovalis (19 percent), which was the dominant, Navicula minima Grun. var. minima (12 percent), Achnanthes lanceolata (Breb.) Grun. var lanceolata (10 percent), Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh. var. curvata (8 percent) and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (8 percent).

At station B2, Surirella ovalis Breb. var. ovalis remained the primary dominant (25 percent) with Navicula gregaria Donk. var. gregaria being co-dominant (18 percent). Two other species were common at this station, Navicula heufleri var. leptocephala (Breb. ex Grun.) Patr. comb. nov. (10 percent) and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (8 percent). Thus four species comprised 61 percent of the diatom community on natural substrates.

Five species were present at station B3, comprising 66 percent of the total diatom community structure. Surirella ovalis Breb. var. ovalis decreased from 25 percent to 8 percent. The dominant species at this station was Nitzschia fonticola Grun. var. fonticola (29 percent) with Navicula pseudoatomus Lund. var. pseudoatomus (11 percent) as the co-dominant. Neither species was common at station B1 or station B2. Other species common at this station were Navicula heufleri var. leptocephala (Breb. ex Grun.) Patr. comb. nov. (10 percent) and Gomphonema bohemicum Reichelt et Fricke var. bohemicum (8 percent).

Rhoicosphenia curvata (Kuetz.) Grun. ex Rabh. var. curvata (18 percent) was the most dominant species of the five that comprised a total of 65 percent of the diatom population at station B4. Surirella ovalis Breb. var. ovalis and Gomphonema bohemicum Reichelt et Fricke var. bohemicum increased 7 and 6 percent, respectively, from station B3. Nitzschia fonticola Grun. var. fonticola (13 percent) and Navicula pseudoatomus Lund var. pseudoatomus (5 percent) decreased in abundance.

At station B5, six species comprised 69 percent of the diatom population, with Navicula pseudoatomus Lund. var. pseudoatomus (25 percent) being dominant. The co-dominant species was Navicula heufleri var. leptoceophala (Breb. ex Grun.) Patr. comb. nov. (12 percent). Other species that were common at this station were Navicula minima Grun. var. minima (10 percent), Nitzschia fonticola Grun. var. fonticola (9.0 percent), Navicula gregaria Donk. var. gregaria (7 percent), and Achnanthes lanceolata (Breb.) Grun. var. lanceolata (6.0 percent). Surirella ovalis Breb. var. ovalis decreased from 15 percent to less than three percent.

Station B6 had only four species together comprising 55 percent of the diatom association. Navicula pseudoatomus Lund var. pseudoatomus decreased from 25 percent to below two percent. Gomphonema parvulum Kuetz. var. parvulum (30 percent) was the dominant at this station. Achnanthes lanceolata (Breb.) Grun. var. lanceolata was present at 11 percent, while Cyclotella meneghiniana Kuetz. var. meneghiniana and Gomphonema angustatum (Kuetz.) Rabh. var. angustatum were both common at 7 percent.

Gomphonema parvulum Kuetz. var. parvulum remained the dominant species (12 percent), with Nitzschia palea (Kuetz.) W. Sm. var. palea (12 percent) also present at station B7. Four other species, Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (8 percent), Nitzschia fonticola Grun. var. fonticola (7 percent), Navicula pseudoatomus Lund. var. pseudoatomus (6 percent) and Achnanthes lanceolata Breb. var. lanceolata (6 percent) together comprised 27 percent of the diatom population at this station.

Station B8 had a very different population dominance. Gomphonema intricatum var. pumila Grun. was the most dominant (25 percent) of four species which together comprised 59 percent of the population at this station. Navicula pseudoatomus Lund. var. pseudoatomus, which was common at station B7, increased from 6 percent to 16 percent. The two other species common at

this station were *Gomphonema angustatum* (Kuetz.) Rabh. var. *angustatum* and *G. parvulum* Kuetz. var. *parvulum* at 11 percent and 7 percent, respectively.

Spring Creek species dominance was similar to Brush Creek but at different percentage levels. Station S1 had five species which comprised 64 percent of the diatom association. *Gomphonema intricatum* var. *pumila* Grun. was the most dominant (38 percent) with *G. angustatum* (Kuetz.) Rabh. var. *angustatum* (8 percent), *G. olivaceum* (Lyn.) Kuetz. var. *olivaceum* (7 percent) and *Navicula heufleri* var. *leptocephala* (Breb. *ex* Grun.) Patr. comb. nov (6 percent) and *Amphora bullatoides* Hohn & Hellerm. var. *bullatoides* (5 percent) following.

At station S2, 54 percent of the diatom population was comprised of four species. Twenty-eight percent of the diatom association was *Rhoicosphenia curvata* (Kuetz.) Grun. var. *curvata*, compared to one percent at station S1. *Gomphonema intricatum* var. *pumila* Grun. (12 percent), *Surirella ovalis* Breb. var. *ovalis* (8 percent) and *Navicula minima* Grun. var. *minima* (6 percent) occurred next in decreasing order of abundance.

Differences in diatom community structure and similarity which occurred between sampling stations were the result of the occurrence, loss and recurrence of uncommon and rare species, each occurring at a level of between five and one percent or less than one percent, respectively. To summarize Appendix XII the five most upstream stations of Brush Creek averaged 47 taxa while stations B6, B7 and B8 averaged 59 taxa. Stations S1 and S2 had 59 taxa and 54 taxa, respectively.

Ash-Free Dry Weight -
A comparison of ash-free dry weight (mg/m^2 and $mg/m^2/day$) showed marked shifts between the sampling stations during May-June 1975. These variations were very different from trends observed for species diversity and evenness. There was a sharp decrease in ash-free dry weight from station B1 to station B2 (Table 67 and 68; Figure 35). Station B1 showed the highest value of ash-free dry weight (190.18 $mg/m^2/day$). A smaller, but also sharp, decrease occurred between stations B2 and B3.

Table 67. PERIPHYTON ASH-FREE DRY WEIGHT (mg/m^2).
IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK
BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Slide position in artificial substrate sampler	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 1	8632.76	1696.17	1443.01	2886.02	582.27	987.32	607.58	430.37	1012.64	14607.33
Slide 4	8328.96	1772.12	1113.90	2278.44	658.22	708.68	582.27	227.84	936.69	9240.34
Slide 7	7164.43	2607.55	734.16	2202.49	NS*	886.06	911.38	253.16	886.06	11695.99
Slide 10	7654.43	1721.08	632.90	1746.80	835.43	1139.22	4582.20	582.27	1999.96	10025.14
Slide 13	7215.06	2202.49	1974.65	NS	354.42	1316.43	5822.68	759.48	NS	12252.94
x	7797.33	1999.88	1179.72	2278.44	607.58	1007.54	2501.22	450.62	1208.84	11564.35
s^2	435812.031	158496.734	300775.86	219187.65	39736.87	54309.05	6289601.77	50439.416	280872.61	4380350.62
s	660.161	397.542	548.43	468.175	199.341	233.043	2507.908	224.587	529.974	2092.929

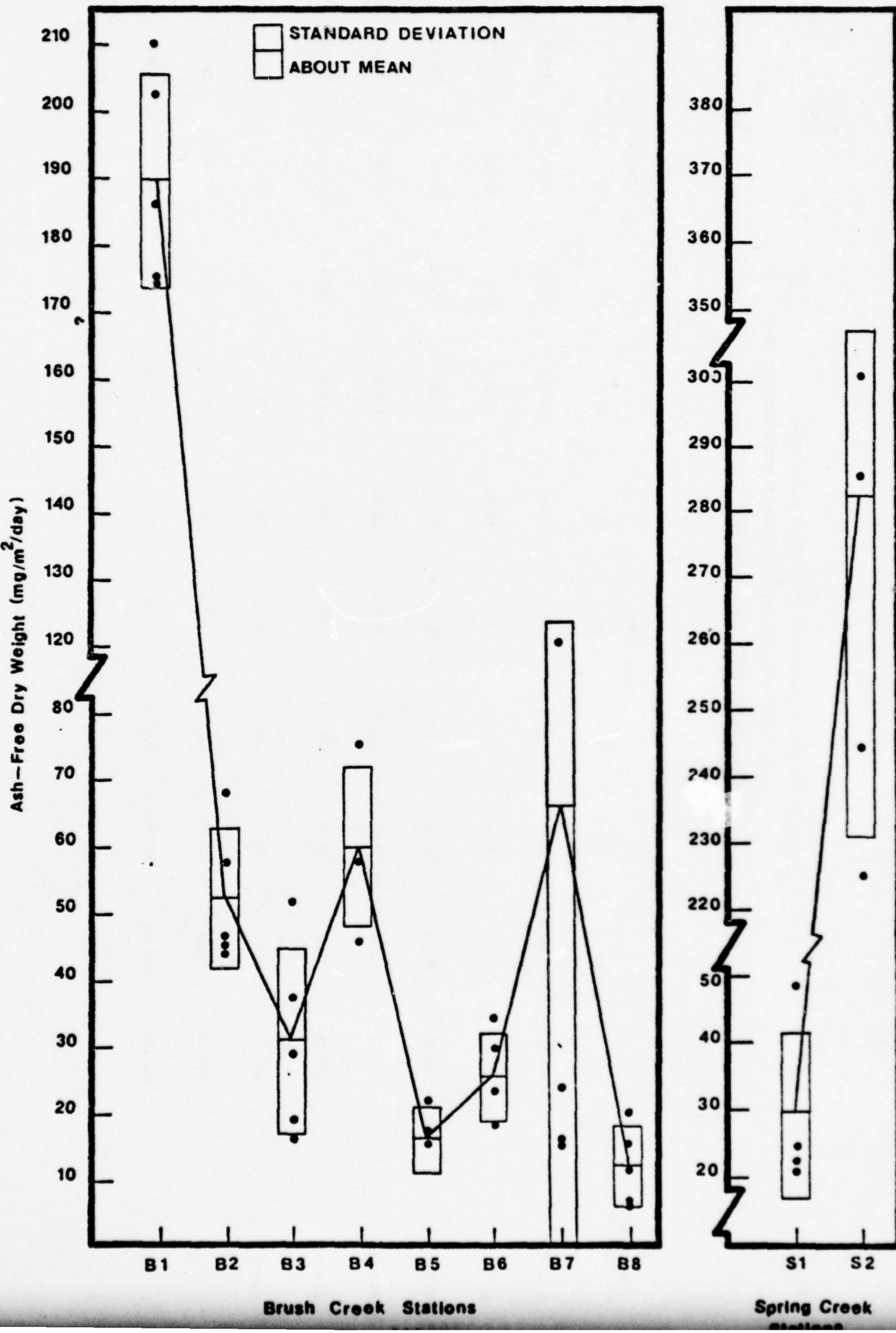
*NS = no sample - slide lost

Table 68. PERIPHYTON ASH-FREE DRY WEIGHT ($mg/m^2/day$).
IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK,
BURLINGTON, IOWA, MAY - JUNE 1975

Slide position in artificial substrate sampler	Brush Creek								Spring Creek	
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 1	210.56	44.64	37.97	75.95	15.32	25.98	15.99	11.32	24.70	356.28
Slide 4	203.14	46.63	29.31	59.96	17.32	18.65	15.32	6.00	22.85	225.37
Slide 7	174.74	68.62	19.32	57.96	NS*	23.32	23.98	6.66	21.61	285.27
Slide 10	186.47	45.29	16.66	45.97	21.98	29.98	120.58	15.32	48.78	244.52
Slide 13	175.98	57.96	51.96	NS	9.33	34.64	153.23	19.99	NS	298.85
Number of days	41	38	38	38	38	38	38	38	41	41
x	190.18	52.63	31.04	59.96	15.99	26.51	65.82	11.86	29.48	282.06
s^2	259.276	109.451	208.202	151.80	27.484	37.59	4355.76	34.935	167.077	2605.95
s	16.102	10.462	14.429	12.321	5.242	6.131	65.998	5.910	12.926	51.048

*NS = no sample - slide lost

FIGURE 35. Periphyton Ash–Free Dry Weight (mg/m²/day) from Five Replicate Artificial Substrates. Iowa Army Ammunition Plant, Brush and Spring Creeks, Burlington, Iowa. May–June 1975



Ash-free dry weight increased at station B4, however it decreased again at station B5. A shift then occurred wherein there was an increase of ash-free dry weight through stations B6 and B7. Station B8 showed the lowest ash-free dry weight value, 11.86 $mg/m^2/day$, than of any of the Brush Creek stations.

At Spring Creek, station S1 showed a low value of 30 $mg/m^2/day$ for ash-free dry weight (Table 67 and 68 ; Figure 35). A sharp increase was observed between station S1 and station S2.

Chlorophyll -

During May-June 1975, the observed trend of chlorophyll was similar to the ash-free dry weight trend. Station B1 of Brush Creek showed the highest value (1.01 $mg/m^2/day$) for chlorophyll a (Table 69 and 70 ; Figure 36). A sharp decrease in chlorophyll a occurred between stations B1, B2 and B3. There was a small increase at station B4 while station B6 showed a decrease in chlorophyll. Samples collected for chlorophyll analysis at station B5 were lost in the field consequently no chlorophyll levels are reported. Chlorophyll a increased between station B6 and B7, but decreased sharply at station B8. The lowest chlorophyll value was seen at station B8 (0.02 $mg/m^2/day$).

Both Spring Creek stations showed higher values of chlorophyll a than the Brush Creek stations (Table 69 and 70; Figure 36). Station S1 had a value of 0.47 $mg/m^2/day$ with an increase occurring at station S2 to 2.05 $mg/m^2/day$.

Autotrophic Index -

The autotrophic index was calculated for all sampling stations on Brush Creek and Spring Creek to determine what percentage of the periphyton community was comprised of algal biomass (Table 71). The chlorophyl ratio before acidification:after acidification was also calculated to show the reliability of the chlorophyll values used in the autotrophic index (Table 72).

Table 69. PERIPHYTON CHLOROPHYLL a (mg/m^2).
IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK,
BURLINGTON , IOWA. MAY - JUNE, 1975

	Brush Creek								Spring Creek	
Slide position in artificial substrate sampler	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 3	16.71	18.32	6.96	14.54	NS*	5.00	0.84	0.33	8.50	75.90
Slide 6	58.75	32.92	5.83	12.25	NS	8.41	3.28	0.56	6.82	86.70
Slide 9	11.42	21.30	5.82	9.48	NS	8.08	7.60	0.72	28.80	83.40
Slide 12	78.20	10.84	6.75	10.70	NS	9.44	26.10	0.99	32.85	88.20
Slide 15	42.36	20.08	7.90	NS	NS	9.91	28.84	1.66	NS	87.40
x	41.49	20.69	6.65	11.74	NS	8.17	13.33	0.85	19.24	84.32
s^2	791.135	63.239	0.757	4.763	NS	3.689	173.367	0.262	182.077	25.48
s	28.127	7.952	0.870	2.182	NS	1.921	13.167	0.512	13.494	5.048

*NS = no sample - slide lost

Table 70 . PERIPHYTON CHLOROPHYLL a ($mg/m^2/day$).
IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK.
BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Slide position in artificial substrate sampler	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 3	0.41	0.48	0.18	0.38	NS*	0.13	0.02	0.01	0.21	1.85
Slide 6	1.43	0.87	0.15	0.32	NS	0.22	0.09	0.01	0.17	2.11
Slide 9	0.28	0.56	0.15	0.25	NS	0.21	0.20	0.02	0.70	2.03
Slide 12	1.91	0.28	0.18	0.28	NS	0.25	0.69	0.03	0.80	2.15
Slide 15	1.03	0.53	0.21	NS	NS	0.26	0.76	0.04	NS	2.13
Number of days	41	38	38	38	38	38	38	38	41	41
x	1.01	0.54	0.17	0.31	NS	0.21	0.35	0.02	.47	2.05
s^2	0.47	0.045	0.001	0.003	NS	0.003	0.121	0.000	0.106	0.015
s	0.686	0.212	0.025	0.056	NS	0.051	0.347	0.013	0.326	0.123

*NS = no sample - slide lost

FIGURE 36. Periphyton Chlorophyll a (mg/m²/day) from Five Replicate Artificial Substrates. Iowa Army Ammunition Plant. Brush and Spring Creeks. Burlington, Iowa. May–June 1975

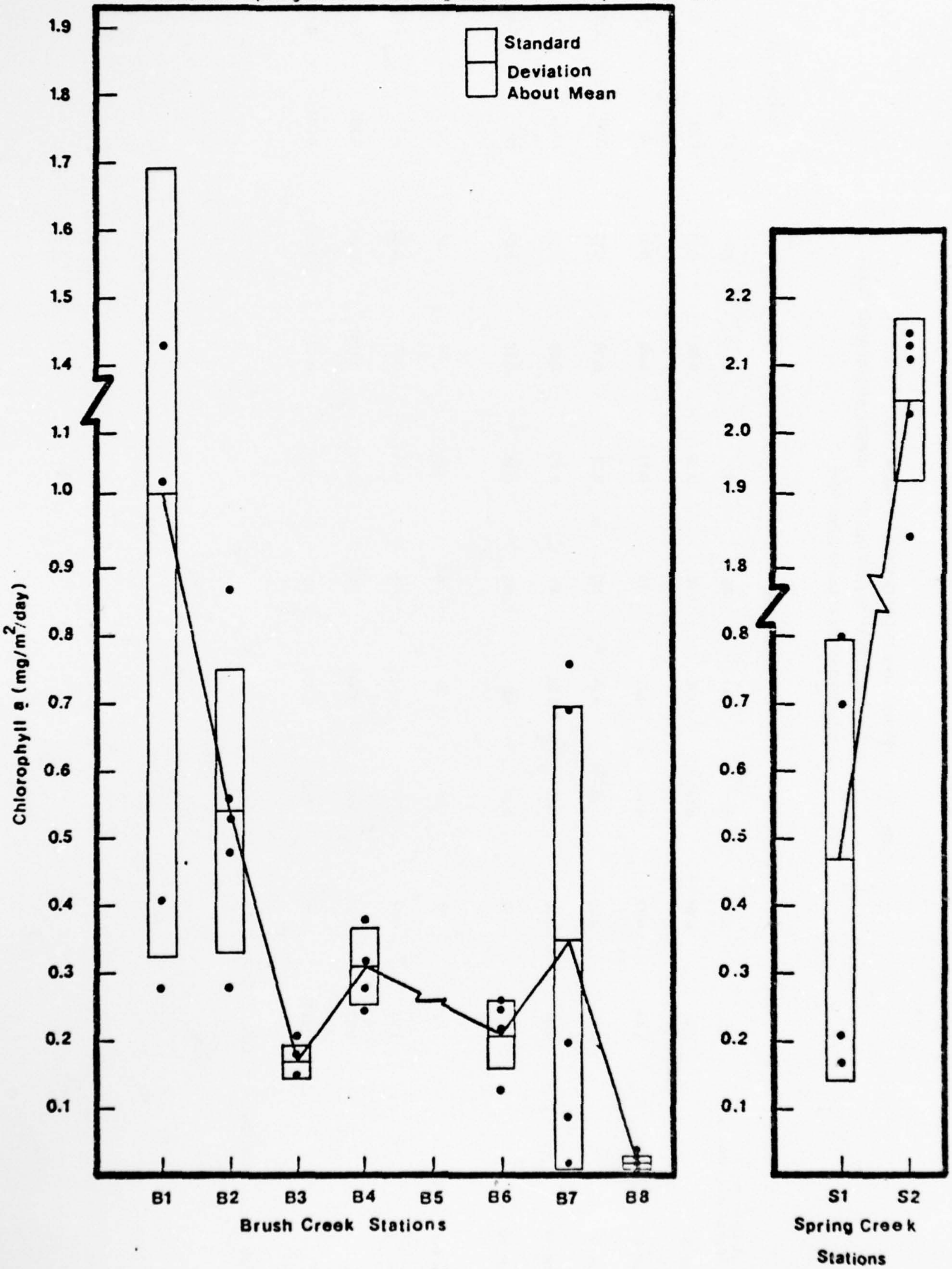


Table 71. Periphyton Autotrophic Index. Iowa Army Ammunition Plant. Brush and Spring Creeks. Burlington, Iowa. May - June 1975.

	Station									
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
*Autotrophic Index	187.93	96.66	177.40	194.07	NS*	123.32	187.63	530.14	62.83	137.15

* Autotrophic Index was calculated from the means of five values ash-free dry weight (mg/m^2) and five values chlorophyll a (mg/m^2) from each station.

Table 72. Periphyton Chlorophyll: Phaeophytin Ratio. Iowa Army Ammunition Plant, Brush and Spring Creeks, Burlington, Iowa. May - June 1975 .

Slide position in artificial substrate sampler	Station									
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 3	1.56	1.60	1.60	1.51	NS*	1.50	1.52	1.44	1.65	1.45
Slide 6	1.58	1.64	1.58	1.63	NS	1.59	1.52	1.62	1.66	1.48
Slide 9	1.57	1.70	1.62	1.54	NS	1.48	1.34	NR**	1.65	1.38
Slide 12	1.38	1.59	1.48	1.66	NS	1.53	1.44	1.77	1.67	1.43
Slide 15	1.63	1.65	1.55	NS	NS	1.54	1.32	1.63	NS	1.52
X	1.54	1.64	1.57	1.58	NS	1.52	1.43	1.61	1.66	1.45
S^2	0.09	0.002	0.003	0.005	NS	0.002	0.009	0.02	0.0001	0.003
S	0.096	0.04	0.05	0.071	NS	0.042	0.09	0.135	0.01	0.05

*NS = No Sample - slide lost

** NR = Invalid Absorbance Reading

Station B5 of Brush Creek was excluded from these determinations because chlorophyll samples were lost.

Most sampling stations on Brush Creek had before acidification:after acidification ratios well above 1.4 indicating that the chlorophyll values used for the autotrophic index were reliable and consisted of little phaeophytin (Table 72). The lowest ratio occurred at station B7 (1.43) which is just below the domestic sewage treatment plant.

All Brush Creek stations except station B2 had autotrophic index values above 100 indicating that a large amount of nonalgal, i.e. heterotrophic, biomass was present. Values increased through stations B3 and B4 with a decrease occurring at station B5. An increase continued through stations B7 and B8. Station B8 showed the highest autotrophic index value of 530.14.

The before acidification:after acidification ratios were high at both Spring Creek stations. Station S1 exhibited a very low numerical value (62.83) for the autotrophic index. It then increased at station S2 above the 100 level to 137.15.

Discussion of Results (May-June)

Species Occurrence -

Species dominance on artificial substrates (May-June) - As seen by the data presented in the previous chemistry section there were important shifts in some chemical parameters. Most important of these changes in concentration as they relate to the biological communities were nutrients, TNT, and chlorides (and other salts) in the aqueous phase. These shifts do not appear to severely alter the stream periphyton communitity within the area studied.

During the May-June survey, diatom species diversity from artificial substrates showed an irregular pattern between stations. The greatest shift took place in the area between stations B3 and B6 and is coupled

with corresponding shifts in nutrient levels and aqueous TNT. This is shown first at stations B4 and B5 where there is a large increase in the mean concentration from the previous station ($< 0.2\ \mu g/l$ at station B3 to $2.5\ \mu g/l$ at B4 and $3.4\ \mu g/l$ at B5). There was a corresponding decrease in the species diversity at both stations to values of 2.3 and 1.8 respectively. At station B6 the TNT dropped to a negligible level, nutrient levels also declined, and there was a corresponding increase in species diversity.

Station B7 of Brush Creek showed a different response toward nutrient levels and aqueous phase TNT levels. Species diversity was the highest at this station. Mean levels of nutrients, e.g., nitrate-N, Kjeldahl-N, phosphorus and ammonia-N, were at nearly maximum levels, and the aqueous TNT concentration was the highest found at any station ($4.0\ \mu g/l$). This station is just below the domestic sewage treatment plant which would account for the high nutrient levels, and possibly the high concentration of TNT(if laundry wastewater or some other unknown waste source containing TNT is processed at this treatment facility). The cause of this trend is uncertain, however there is a distinct possibility that the wastes discharged just above station B7 closely followed the stream bank and did not mix well with the stream. Physical characteristics of the stream resulted in the periphyton samplers maintaining a position in the center of the stream or slightly opposite the flume of the wastewaters. Therefore samplers may not have received the full impact of the wastewater. Collections for natural substrates were taken from several points on both sides of the stream and these data, discussed later, are more indicative of the diatom community at station B7 and may therefore show more realistic affects.

Species diversity decreased slightly at station B8. This does not correspond to the decrease in nutrient levels and aqueous TNT, but is probably due to the mats of Cladophora that completely covered the periphyton samplers inhibiting diatom growth. (Cladophora growth was not, however, attached to the slides, but rather was entangled on the floats of the sampler, allowing little light penetration).

In the Spring Creek system, the low species diversity at station S1 probably resulted from siltation caused by construction farther upstream. However the chloride concentration was higher (45.5 mg/l) at this station than at station S2 (35.3 mg/l). Low levels of munitions compounds and nutrients were found in the waters of both stations (see Table 3 Chemistry Section).

Application of the truncated normal curve to the species data from each station showed the height of the mode to be very low at stations B1 and B8 of Brush Creek and stations S1 and S2 of Spring Creek. The remaining stations had much higher mode heights. These curves suggest normal or stable diatom communities in the areas of industrial waste discharge. Wastes discharged into Brush Creek did not significantly alter the diatom species complex and community stablity at any station.

These trends, seen from the artificial substrates, indicated that station B1 and B8 (reference and recovery zones, respectively) of Brush Creek had effects caused by the natural characteristics of the stream and not industrial waste effluents. The remaining stations did not show any real adverse effects from the industrial effluents. Spring Creek was characterized by a stable periphyton community with siltation disrupting it slightly.

Species dominance shifted between the eight stations of Brush Creek, however one diatom species, *Achnanthes lanceolata* (Breb.) Grun. var. *lanceolata*, was always common. This species often occurs in alkaline waters (alkaliphil), having optimum growth at pH 7.2 - 7.5 but can exist in pH levels of up to 9[44]. This species also is indifferent to chlorides (<500 mg/l)[32]. The common occurrence of this species in Brush Creek correlates with its recorded tolerance regimes and the water chemistry in which it is found; i.e., pH 8.25 - 9.30 and chloride concentration of 58.6 - 162 mg/l (see Table 2 Chemistry Section).

Within the Brush Creek system, five diatom species, including *Achnanthes lanceolata* (Breb.) Grun. var. *lanceolata*, were common, although their

relative abundance varied between stations. These species were *Gomphonema bohemicum* Reichelt et. Fricke var. *bohemicum*, *G. parvulum* Kuetz. var. *parvulum*, *Nitzschia palea* (Kuetz.) W. Sm. var. *palea*, and *Cocconeis pediculus* Ehr. var. *pediculus*. These species were all dominant, i.e., common or abundant, at one or more of the stations (refer to Biology Results), and have recorded tolerance regimes[44] very similar to *Achnanthes lanceolata* (Breb.) Grun. var. *lanceolata*. *Cocconeis pediculus* Ehr. var. *pediculus* is also able to tolerate higher salt levels (Cl^-)[44].

Pinkham and Pearson coefficient of association was used to group the Brush Creek stations on the basis of species occurrence. Stations B2, B5, and B6 had the same dominant and co-dominant species and were most similar. Species occurrence and dominance were similar between stations B3, B4, and B7, causing them to be grouped together.

Two of the proximal station pairs, B3-B4 and B5-B6, were similar above the 50 percent level (55 percent and 62 percent, respectively) (Table 62). These station pairs were not affected by different industrial waste effluents. The remaining station pairs, B2-B3, B4-B5, and B6-B7 had one of the stations directly affected by an effluent(s). Station B2 received effluent wastes from I1, I2, I3, and I4 and was similar at the 24 percent level to station B3, which received no effluent waste except dilutions from the previous industrial effluents mentioned. Stations B4 and B5 each had different waste effluents affecting the periphyton community. These effluents were the TNT runoff and I5 at B4 and I7 at B5. These stations were similar at only 18 percent. Station B7 was directly below the domestic sewage treatment, and was similar to station B6 at only 39 percent.

From these observations it can be concluded that the industrial effluents under study directly affected the periphyton populations on artificial substrates at stations immediately downstream, however recovery was occurring at the stations that were not in direct contact with the effluent discharge. The overall observation of Brush Creek indicates that recovery is occurring rapidly and affects on the periphyton community are apparently only short term.

Dominant species at station S1 and station S2 were Cocconeis placentula var. euglypta (Ehr.) Cl. and Rhoicosphenia curvata (Kuetz.) Grun. ex curvata, respectively. Both species are alkaliphils, found most frequently in water with pH levels of 7-9 and are indifferent to chlorides[44]. These two stations had lower pH levels (8.4 - 8.5) and chloride levels (35.3 - 45.5 mg/1) than the Brush Creek stations. Species dominance at stations S1 and S2 were similar to stations B1 and B8 of Brush Creek. Thus, the occurrence of these species caused these four stations to be grouped according to the Pinkham and Pearson coefficient of association.

In Brush Creek, non-diatom algae species occurrence shifted between two dominants, Protoderma viride Kuetz. and Chroococcus dispersus (Keissl.) Lemm. The non-diatom algae comprised most of ten over 50 percent of the population in Brush Creek. The trend of species richness was not similar to diatom species diversity. Values of species richness were low through station B5 with a sharp increase occurring at station B7. This increase corresponds to the higher nutrient levels at this station due to the domestic sewage treatment plant. Station B8 had a very low species richness, due to the large mats of Cladophora that covered the periphyton samplers during the incubation period.

Species richness values for stations S1 and S2 of Spring Creek were very high. An increase occurred between the two stations which followed the trend for diatom species diversity. Siltation from upstream construction and a higher chloride level probably caused the lower species richness at station S1.

Species Occurrence on Natural Substrates (May - June) - The biota collected from natural substrates were affected by more than the aqueous phase chemistry. Since they were in contact with the bottom of the stream, chemistry from the sediments was important. The most important parameters in the sediment phase are total solids, total volatile solids, COD, TNT, nutrients, and metals.

It was shown that combined diatom species diversity from natural substrates was very different from the trend seen on artifical substrates. Diversity on natural substrates was high at station B1 (reference station) where nutrients and aqueous TNT levels were low. Diatom diversity continued to decline through station B5. This reach of the stream receives the major industrial effluents and TNT levels increase (refer to Chemistry; Table25 and 55). Species diversity sharply increased at station B7 (the highest diversity of any one station) where nutrient levels and aqueous TNT were very high. The cause of this phenomenon, which also occurred on the artificial substrates, is uncertain but is due probably to the same factor (i.e. localized or minimal mixing of industrial wastes) discussed with reference to the artificial substrates. The decrease in diversity occurring at station B8 was due to Cladophora mats. The occurrence of Cladophora in this area of Brush Creek is the result of several physico-chemical factors. Most important is that occurrence is limited to spring and early summer periods. This is in response to water temperature and solar incidence and is typical in the life cycle of this taxon. Also stream conditions are more favorable in this area for the attachment of Cladophora and nutrient levels are probably sufficient to support large masses.

The Spring Creek stations showed the same increase in diversity on natural substrates from station S1 to station S2 as was seen on the artificial substrates. Station S1, which is not affected by industrial effluents received light siltation from construction work upstream, which is probably the cause of the low diversity at this station.

Diatom species diversity for samples collected from the sediments only did not indicate any affect due to the TNT found in the sediments. The diversity values for all samples were well over 2.2 indicating that each microhabitat was very diverse. Samples were scanned while alive to find a ratio of live to dead cells; over 75% were found to be living, therefore the diversity values are reliable for each station.

Species occurrence and dominance on natural substrates shifted greatly between the stations of Brush Creek. There was no one common species that occurred at every station. _Surirella_ _ovalis_ Breb. var. _ovalis_ was dominant at stations B1 and B2. This species has its optimum growth in waters with high chlorides and pH of over 8.5[44]. This corresponds with the chemistry found at these two stations (refer to Table 2 Chemistry section).

The remaining stations each had a different dominant species. Several common species were _Nitzschia_ _fonticola_ Grun. var. _fonticola_, _Rhoicosphenia_ _curvata_ (Kuetz.) Grun. _ex_ Rabh. var. _curvata_, _Gomphonema_ _parvulum_ Kuetz. var. _parvulum_, and _G_. _intricatum_ var. _pumila_ Grun. which all are indifferent to chlorides and grow well in pH levels up to 9.0.

Results of the application of the Pinkham and Pearson coefficient of similarity indicated that stations were not similar by dominant or co-dominant species in particular. All of the proximal stations on Brush Creek were similar above 50 percent, e.g., B4-B5, B1-B2,

B2-B3, which is a good indication that extreme changes to the periphyton community on the natural substrate of the stream are not occurring as a result of industrial waste effluents. However, since the species association occurring on natural substrates is more complex (i.e. diverse), and the dominant species occur at a lower percentage, the effects of the industrial wastes are not as evident as reflected by comparisons of artificial substrate data. The species association occurring on artificial substrates is less complex and the dominant species occurred at a higher frequency therefore physico-chemical factors causing minor changes in the species association had a greater impact on diversity and similarity comparisons. Thus, affects seen on artificial substrates may be somewhat more obvious. However, it was shown that these affects were short term and recovering occurred within the study area.

Dominant species occurring at the Spring Creek stations were similar; likewise these two stations were paired by the Pinkham and Pearson coefficient of similarity. The dominant species were Gomphonema intricatum var. pumila Grun. and Rhoicosphenia curvata (Kuetz) Grun. ex Rabh. var. curvata. These species were also seen in Brush Creek and their autecology was discussed previously. Though these species can tolerate high chloride and pH levels, the nutrients, chlorides and aqueous TNT were all found at low levels at these stations.

The pheriphyton community of natural substrates appeared to relate more with the sediment phase chemistry than the aqueous phase. Though the sediments showed higher levels of TNT at stations B2, B4 and B7, diatom composition of the stations was not altered greatly. The Brush and Spring Creek systems represent very stable and healthly periphyton populations occurring upon the natural substrate surroundings.

Ash-Free Dry Weight -

The trend of ash-free dry weight in Brush Creek varied between

stations (refer to Biology Results). The trend appeared to correspond to the levels of COD, TS, and TVS found in the sediments. Increases and decreases in ash-free dry weight that occurred between stations were significant when the analysis of variance was applied (Table 73). The change in ash-free dry weight between stations S1 and S2 of Spring Creek is also significant (Table 73).

Chlorophyll -

Periphyton trends derived from chlorophyll a showed patterns similar to ash-free dry weight. Changes which occurred between the stations were of a lesser magnitude than ash-free dry weight, however, these changes were shown to be significant by the analysis of variance (Table 74).

Autotrophic Index -

The autotrophic index was another comparison of periphyton associations applied to the two stream systems under study. This index was calculated from data obtained from the artificial substrates. Using the value of 100 described by Weber[36,59] as the level of significance between autotrophic and heterotrophic, both streams showed indications of most areas being heterotrophic.

Ash-free dry weight showed greater increases and decreases than chlorophyll, indicating either that the population is composed of some heterotrophic organisms (i.e., fungi, bacteria, and protozoa), or that organic detrital material is present. This fact also explains the high autotrophic index values seen at the stations.

Total volitale solids, total solids and chemical oxygen demand in the sediments varied between stations but was generally at high levels. This accounts for inorganic or organic detrital materials being present in both stream systems. The presence of this material increases the potential occurrence of non-viable organic matter in the periphyton mass. There is thus the possibility that the ash-free dry weight may not totally reflect living periphyton.

TABLE 73. ANALYSIS OF VARIANCE FOR ASH-FREE DRY WEIGHT. IOWA ARMY AMMUNITION PLANT
BRUSH AND SPRING CREEKS
BURLINGTON, IOWA
MAY-JUNE, 1975

BRUSH CREEK (excluding station B1)

Source	df	SS	MS	F
Total	32	32643.4282		
Treat (between)	6	13121.8187	2186.9698	2.91*
Error (within)	26	19521.6095	750.8311	

F (0.95) = 2.47 * significant difference

BRUSH CREEK (including station B1)

Source	df	SS	MS	F
Total	37	134672.2124		
Treat (between)	7	114113.4993	16301.9285	23.79*
Error (within)	30	20558.7132	685.2904	

F (0.95) = 2.33 * significant difference

SPRING CREEK

Source	df	SS	MS	F
Total	7	133952.87		
Treat (between)	1	123380.28	123380.28	70.02*
Error (within)	6	10572.59	1762.10	

F (0.95) = 5.99 * significant difference

Note: based on $mg/m^2/day$

TABLE 74. ANALYSIS OF VARIANCE FOR CHLOROPHYLL a
IOWA ARMY AMMUNITION PLANT
BRUSH AND SPRING CREEKS
BURLINGTON, IOWA
MAY-JUNE,1975

BRUSH CREEK (Excluding station B1)

Source	df	SS	MS	F
Total	28	1.4701		
Treat (between)	5	0.7837	0.1567	5.25*
Error (within)	23	0.6864	0.0298	

F (0.95) = 2.64*

BRUSH CREEK (including station B1)

Source	df	SS	MS	F
Total	33	5.7661		
Treat (between)	6	2.8166	0.4694	4.30*
Error (within)	27	2.9495	0.1092	

F (0.95) = 2.46*

SPRING CREEK

Source	df	SS	MS	F
Total	8	5.96		
Treat (between)	1	5.58	5.58	102.79*
Error (within)	7	0.38	0.05	

F (0.95) = 5.59*

Note: based on $mg/m^2/day$

Excessively high or disproportionate levels of ash-free dry weight created by non-viable organic material would lead one to describe the periphyton as heterotrophic when in reality it is not. Station B2 of Brush Creek and station S1 of Spring Creek had low autotrophic index values (96.66 and 62.83, respectively) resulting from chlorophyll a levels being proportionally the same as the ash-free dry weight values.

As seen by the biological data presented, there was a change in the periphyton community on artificial substrates in Brush Creek. These changes, however, did not affect the stream on a long term basis. Periphyton community analysis of the natural substrates showed the stations to be very similar with no change occurring. The stream system as a whole, however, does not show any extreme detrimental effects on the periphyton community resulting from the industrial waste effluents under consideration.

Measurement of Adenosine Triphosphate (ATP)

In an effort to determine the viability of periphyton fractions the measurement of ATP was undertaken. These measurements were taken from periphyton growing on artificial substrates during May-June (Table 75A). Previous results have shown very similar trends between ash-free dry weight and chlorophyll a. These trends were parallel. In a like manner periphyton ATP levels varied, decreasing and increasing parallel to ash-free dry weight and chlorophyll a.

The first comparison of these data was to relate ATP with measured dry weight. Weber [36] indicated that an average of 2.4 μg ATP was contained per milligram dry weight cell mass. Algae cultures produced a range of

0.03 to 3.4 g ATP/milligram dryweight[36] having a mean of 1.16. Laboratory experiments of this project using Chlorella as a test species and boiling Tris buffer extraction, yielded 0.3 μg ATP/milligram dry weight with a calculated recovery of 98%. Literature sources indicate Chlorella vulgaris to yield 2.0μg ATP/mg dry weight[36]. From this information it was concluded that the extraction procedure utilized provided only about 12.5 to 15 percent extraction efficiency. With this in mind a factor of "eight" was applied to the measured ATP data to compensate for the extraction inefficiency. These corrections have been applied to the tabular data (Table 75 and 76), and were used to complete this Results and Discussion section.

Rather than relating ATP to dry weight as reported from pure culture studies in the literaure, ATP measured from natural periphyton in this study was related to ash-free dry weight since natural periphyton would contain extraneous, non-living material. It was felt that the use of ash-free dry weight would more closely reflect living periphytic masses. The data indicate much lower values of ATP/ash free dry weight from natural populations as compared to culture extractions. Measured ATP values, with the correction factor, ranged from 16 to 264 $\mu g/m^2$ (Table 75).

Using the figure of 250 by Holm-Hansen[43] to convert measured ATP to organic biomass the yield of organic biomass was much lower than the measured ash-free dry weight (mg/m^2). For example, at station B2 the corrected ATP value was 168 $\mu g/m^2$, multiplied by 250, yielded 42 mg/m^2 organic biomass. This relates to a measured ash-free dry weight of 2000 mg/m^2. (Table 75). This indicates: (a) there was a problem in the extraction and measurement of ATP, i.e. low efficiency, or (b) the measured ash-free dry weight was larely composed of non-viable organic material.

Another factor published by Holm-Hansen[42] was that 0.35 percent of organic biomass is ATP. Using station B2 as an example (Table 75),

TABLE 75. CONVERSION OF PERIPHYTON ATP TO ORGANIC BIOMASS AND PERIPHYTON ORGANIC BIOMASS TO ATP USING FACTORS PUBLISHED BY SEVERAL AUTHORS. IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEKS, BURLINGTON, IOWA. MAY-JUNE 1975.

Station	Measured ATP (average) (μg/m^2)	μg ATP/ mg Org. Wt. μg/mg	ATP Convert. to Biomass (mg/m^2)	0.35% Biomass = ATP	0.175% Biomass = ATP	Measured Org. Biomass (mg/m^2)
B1						7797
B2	168	0.084	42.0	7.0	3.50 mg	2000
B3	78.4	0.066	19.6	4.2 mg	2.06 mg	1180
B4	105.6	0.046	26.4	7.97 mg	3.98 mg	2278
B5	240.0	0.395	60.0	2.12 mg	1.06 mg	608
B6	49.6	0.049	12.4	3.52 mg	1.76 mg	1008
B7	264.0	0.106	66.0	8.75 mg	4.38 mg	2501
B8	16.0	0.035	4.0	1.58 mg	0.79 mg	451
S1	91.2	0.075	22.8	4.23 mg	2.12 mg	1209
S2	208.0	0.018	52.0	40.47 mg	20.23 mg	11564
		Average 2.4 μg ATP/ mg dry wt. (Weber)	ATP x 250 = total cellular biomass (Holm-Hansen)	Average 0.35% of org. biomass is ATP (Holm-Hansen)	range 20-50% of 0.35% biomass is ATP (Holm-Hansen)	

TABLE 75A. IAAP PERIPHYTON ATP VALUES WITHOUT APPLIED CORRECTION FACTORS

Station	Mean ± Standard Deviation ($\mu g/m^2$)	Percent Recovery of Standard
B1	---	
B2	21.0 (1)*	
B3	9.8 ± 1.4 (5)	112.5
B4	13.2 ± 0.75 (3)	99
B5	30.0 ± 8.5 (2)	95
B6	6.2 (1)	
B7	33.0 (1)	
B8	2.02 (1)	
S1	11.4 ± 2.6 (3)	98
S2	26.0 ± 3.5 (2)	

*Parentheses indicate number of replicates

TABLE 76. PERIPHYTON ORGANIC BIOMASS, CHLOROPHYLL, AND ATP SUMMARY. IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. MAY-JUNE 1975

Station	Org. Wt. (mg/m^2)	Non-Algal Biomass (mg/m^2)	Algal Biomass (mg/m^2)	Chl. a (mg/m^2)	ATP (mg/m^2)
B1	7797	5100.2	2696.8	41.49	-
B2	2000	655.2	1344.8	20.69	0.168
B3	1180	747.7	432.3	6.65	0.078
B4	2278	1514.9	763.1	11.74	0.106
B5	607	-	-	-	0.240
B6	1007	475.9	531.1	8.17	0.050
B7	2501	1634.5	866.5	13.33	0.264
B8	451	395.7	55.3	0.85	0.016
S1	1209	(-41.6)	1250.6	19.24	0.091
S2	11564	6083.2	5480.8	84.32	0.208

0.35 percent of the measured ash-free dry weight (0.0035×2000 mg/m^2), yields expected ATP levels of 7.0 mg/m^2. Holm-Hansen [42] indicates this may vary by 50 percent, therefore, if all the material recorded as ash-free dry weight was living, viable organic biomass, the measured levels of ATP should be 3.5 to 7.0 mg/m^2. At station B2 the corrected, measured ATP was 168 μg/m^2 or 0.168 mg/m^2. This was about 4.8 to 2.4 percent of the ideal values.

A manipulation of data reveals that when using the organic biomass calculated by converting measured ATP times the 250 factor the mean yield of organic biomass was about 2.4 percent of the measured ash-free dry weight. For example, station B2 (Table 75):

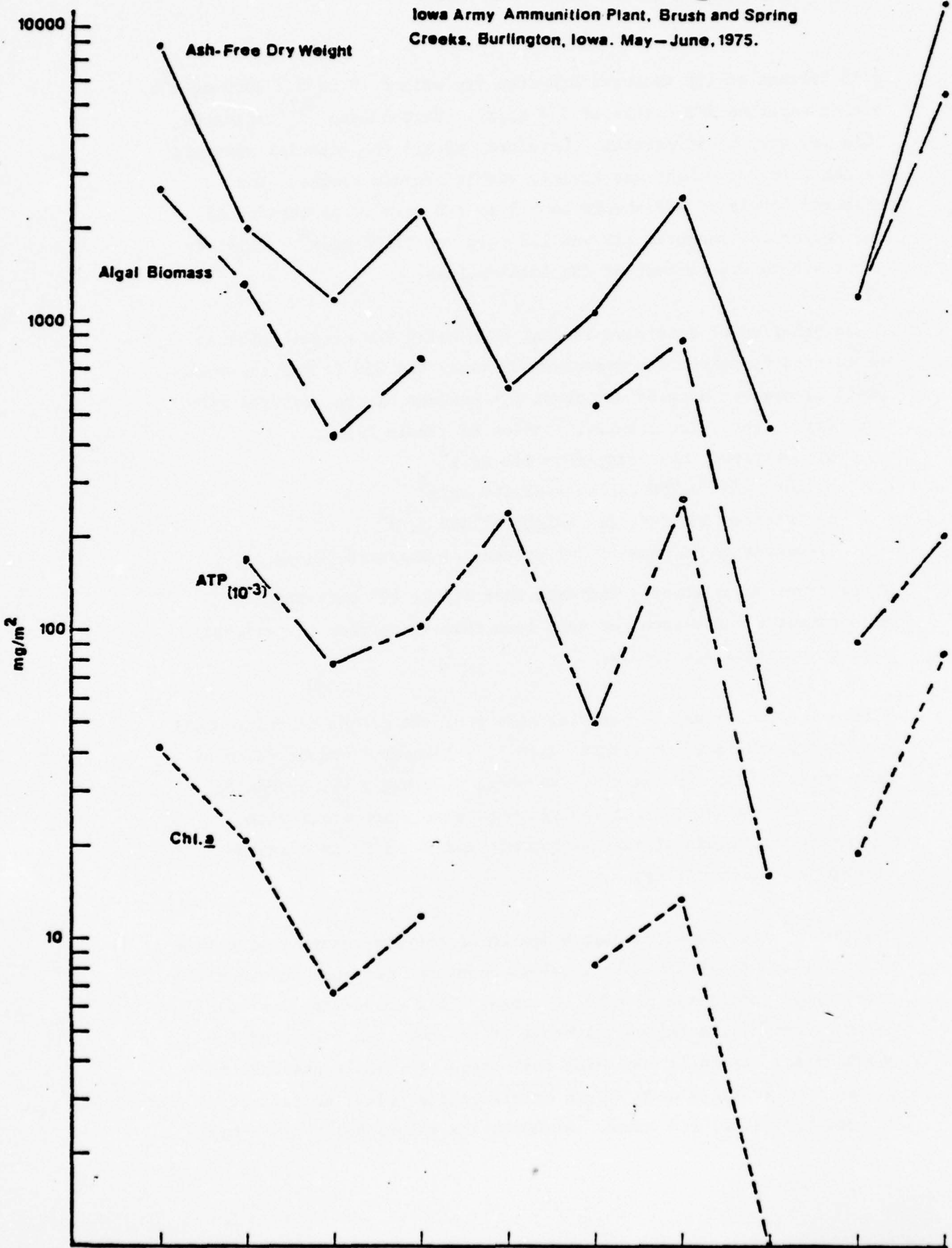
a) corrected, measured ATP = 168 μg/m^2
b) 168 μg/m^2 x 250 factor = 42,000 μg/m^2
c) measured ash-free dry weight = 2000 mg/m^2
d) converted biomass is 2.1 percent of measured "biomass"

These trends consistantly indicate that either ATP extraction and measurement was not good, or that less than 95 percent of periphytic microcommunities are viable.

Figure 37 indicates the parallel nature of the trends of chlorophyll a (mg/m^2), ash-free dry weight (mg/m^2), chlorophyll converted to biomass (mg/m^2), and ATP (mg/m^2). As shown previously the trends of ash-free dry weight and chlorophyll were nearly identical with the resultant values of the autotrophic index indicating heterotrophic microcommunities.

Collins [45] has indicated from a search of the literature that a factor of 65 applied to chlorophyll a values corrected for phaeophytin will give a good indication of algal biomass. This conversion was made using chlorophyll a (mg/m^2) although it had not been corrected for phaeophytin. Table 72 indicates that there was little phaeophytin in the samples since most before acidification: after acidification ratios were high or near the ideal, 1.7 value. Although the chlorophyll values may

FIGURE 37. Summary Comparison of Periphyton Ash-Free Dry Weight, Algal Biomass, Chlorophyll a, and ATP. Iowa Army Ammunition Plant, Brush and Spring Creeks, Burlington, Iowa. May—June, 1975.



have a very small error, it was found that about 40 percent of the periphyton mass was composed of algae, range 12 to 67 percent (Table 76 and 77). The remaining 60 percent ash-free dry weight is therefore composed of heterotrophic species, i.e., bacteria, fungi, yeasts, protozoans, and spores, or non-living organic material, i.e., detritus. This is reflected by the autotrophic index. (Tables 71 and 78).

The plot of ATP (10^{-3} mg/m^2) produces a trend very similar to chlorophyll and ash-free dry weight (Figure 37). Unfortunately chlorophyll samples were missing from stations B1 and B5 therefore the trends are not complete.

Relationship of ATP to Ash-Free Dry Weight and Chlorophyll - The utility of ATP as a measurement of periphyton activity is limited by the extraction and recovery procedures. The application of this measurement to periphyton collected from artificial substrates in Brush and Spring Creeks relate to other measurements in trend only. The similar trends of chlorophyll a, ash-free dry weight, algal biomass, and ATP indicated that no large fraction of the periphyton was non-viable. A disproportionate increase in ash-free dry weight with little or no corresponding increase in ATP would suggest a non-viable organic fraction was present in the periphyton.

An attempt to relate measured values of ATP and organic biomass to correlations found in the literature was inconclusive. If measured levels of ATP are correct then it is estimated that less than 95 percent of the periphyton microcommunity is living, viable biomass. On the otherhand, if the measured ash-free dry weight represents a completely (100 percent) living, viable biomass then the measured, and once corrected, ATP measurements are still in error by about 95 percent.

The use of ATP in ratios with chlorophyll and ash-free dry weight

TABLE 77. ESTIMATE OF PERIPHYTON ALGAL BIOMASS AND PERCENT ALGAL BIOMASS. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS, BURLINGTON, IOWA. MAY-JUNE 1975

Station	Org. Wt.	*Chl.a	Algal Biomass'	Percent
B1	7797	41.49	2696.8	34.6
B2	2000	20.69	1344.8	67.2
B3	1180	6.65	432.3	36.6
B4	2278	11.74	763.1	33.5
B5	607	-	-	-
B6	1007	8.17	531.1	52.7
B7	2501	13.33	866.5	34.6
B8	451	0.85	55.3	12.3
S1	1209	19.24	1250.6	**(103.4)
S2	11564	84.32	5480.8	47.4

$\overline{X} = 39.9$

*chlorophyll not corrected for phaeophytin (see discussion)

**value excluded in calculations of mean percent

'percent algal biomass derived by factor of 65 to convert phaeophytin corrected chlorophyll a values to organic biomass (algal biomass). (28)

TABLE 78. RATIOS OF ORGANIC WEIGHT: ATP AND CHLOROPHYLL a : ATP. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS, BURLINGTON, IOWA. MAY-JUNE 1975

Station	Org. Wt.	AI	Chl a	ATP	*Org.Wt./ ATP	Chl a/ ATP
B1	7797	188	41.49	-	-	-
B2	2000	97	20.69	0.168	109	123
B3	1180	177	6.65	0.078	123	85
B4	2278	194	11.74	0.106	146	110
B5	607	-	-	0.240	50	-
B6	1007	123	8.17	0.050	142	163
B7	2501	187	13.33	0.264	97	50
B8	451	530	0.85	0.016	167	53
S1	1209	63	19.24	0.091	115	211
S2	11564	137	84.32	0.208	236	405

*The values of this ratio are expressed as its square root to achieve lower numbers for ease of comparison.

was inconclusive. Variations in these ratios in their simple form could not be related definitively to activity, i.e., stimulation or inhibition, of the periphyton microcommunity. The discussion which follows is somewhat inconclusive, may be confusing to the reader, and is included more for a matter of record from which future research can be initiated.

Organic Weight/ATP Ratio -

The ratio of organic weight/ATP should increase as there is an increase in ash-free dry weight (organic weight), especially non-viable organic mass, and will decrease as organic biomass decreases or reaches total viability and ATP increases. This did occur to a certain extent in the Brush Creek system (Table 78).

1) As ash-free dry weight (organic weight) decreased between station B2 and B3, coupled with a slight decrease in ATP, this ratio increased indicating a lower activity of the organic "biomass".
2) Between stations B3 and B4 there was an increase in ash-free dry weight, a slight increase in ATP, and an increase in the value of this ratio. This again indicates a lower activity of the periphyton mass, or the disproportionate addition of non-viable materials to the mass.
3) Between stations B4 and B5 there was a great decrease in the value of the organic weight ATP ratio accompanied with an increase in ATP and a decrease in ash-free dry weight. This suggests a very viable periphyton community composed of little non-viable organic mass.
4) Ash-free dry weight increased between stations B5 and B6, ATP decreased, and the ratio increased markedly. This would indicate a moribund state of the periphyton, an increase in non-living organic material, or the death of the periphyton community.

5) Increases in ash-free dry weight and ATP between stations B6 and B7 produced a decrease in the ratio. Again this suggests a more healthy periphyton microcommunity with little non-viable organic "biomass".
6) Sharp decreases were observed in ash-free dry weight and ATP between stations B7 and B8, which was accompanied by a rise in the index suggesting a moribund condition. This is quite possible since Cladophora mats covered the artificial substrate samples limiting light penetration and producing a quiescent zone for the deposition of particulate material.
7) In the Spring Creek system there was an increase in ash-free dry weight and ATP, with a sharp increase in this ratio. Again this indicates decreased activity or a disproportionate increase of non-living organic material.

These variations in the organic "biomass"/ATP ratio may also reflect a change in the periphyton composition to species with more or less ATP since it has been shown in the literature that ATP/dry weight varies between organisms. The organic weight/ATP ratio varies in a manner similar to the autotrophic index (AI), increasing or decreasing along with the autotrophic index at all Brush Creek stations except station B7 (Table 78). This may indicate that what was termed a "heterotrophic" community in Brush Creek may be in part moribund biomass or non-living organic material. Although the periphyton is considered heterotrophic at station B7, below the waste treatment facility, it was apparently a living, active community because of the high ATP levels and low value of the organic biomass/ATP ratio.

Chlorophyll *a*/ ATP Ratio -

The ratio of chlorophyll *a*/ATP more directly reflects a living fraction of the periphyton biomass. It was also shown previously that the periphyton was composed of about 40 percent algal biomass. This ratio will increase as chlorophyll increases or ATP decreases.

A decrease in ATP with little shift in chlorophyll will increase this ratio indicating a moribund state of the algal fraction. On the otherhand, a disproportionate increase in heterotrophic species over autotrophic species will increase the ATP level and decrease the ratio. The following trends were observed (Table 78):

1) Between stations B2 and B3 there was a decrease in chlorophyll, algal biomass, ATP, and total ash-free dry weight. The chlorophyll/ATP ratio also decreased.
2) Between stations B3 and B4 these measurements increased in value and likewise there was an increase in this ratio.
3) There was a decrease in chlorophyll between stations B4 and B6, a decrease in ATP, and an increase in this ratio. Between these stations there was a slight decrease in ash-free dry weight. This indicates that there may be a change in the ratio at non-algal species to algal species, or that the algal species at station B4 (higher chlorophyll level) were moribund. The autotrophic index suggests a shift to a more autotrophic community between these stations.
4) There was a decrease in this ratio between stations B6 and B7 which was accompanied with an increase in chlorophyll and ATP. This would suggest that there was a disproportionate increase in non-algal species at station B7. The autotrophic index indicates the latter to be true.
5) At station B8 there was a decrease in chlorophyll and other measurements, and the value of the chlorophyll/ATP ratio was low. This low level indicates a non-algal fraction of the community predominates which is also reflected by a very high autotrophic value.
6) In the Spring Creek system the large increase in chlorophyll and not so large increase in ATP produced and increase in the ratio.

The comparison of this ratio to the autotrophic index suggests that the chlorophyll/ATP ratio more closely reflects a change in the ratio of algal to non-algal species than the activity or condition of the algal fraction.

Autotrophic Index/ATP Ratio (AI/ATP) - This ratio may give an indication of the condition of the periphyton community. This ratio is expressed as:

$$\frac{\dfrac{\text{ash-free dry wt (mg/m}^2\text{)}}{\text{chlorophyll } \underline{a} \text{ (mg/m}^2\text{)}}}{\text{ATP (mg/m}^2\text{)}}$$

The following variations can occur:

1) If the autotrophic index (numerator) increases in value and ATP remains constant the value of the ratio will increase. This indicates that the increasing "heterotrophic" nature of the periphyton may actually be non-viable ash-free dry weight.
2) If the autotrophic index (numerator) remains constant and the ATP increases, the ratio will decrease, and if ATP decreases the ratio will increase. This may reflect the condition of the periphyton.
3) If the numerator (autotrophic index) increases and ATP increases the ratio may not change.

When the autotrophic index was compared to this ratio those stations which were labelled as autotrophic, i.e., values less than 100, had low AI/ATP ratios. This is seen at stations B2 and S1. Those stations which were high heterotrophic had a high autotrophic index/ATP ratio, e.g., station B8. This suggests a large fraction of non-living organic material, or moribund biomass.

If a periphyton community was autotrophic, i.e., AI less than 100, and the AI/ATP ratio was high, resulting from low ATP values, the

community would be a moribund autotrophic association. On the other-hand, if the community was autotrophic, i.e., AI less than 100, and the AI/ATP ratio was low, resulting from a high ATP, the community would be a healthly, active algal association.

A community labelled as heterotrophic, i.e., AI greater than 100, with a high AI/ATP ratio resulting from low ATP would be considered a moribund heterotrophic association or it is composed of a large amount of non-living organic mass or detritus. If the community was heterotrophic, i.e., AI greater than 100, and the AI/ATP ration was low resulting from a high ATP value, the community would be a living viable association comprised mostly of non-algal species.

In the Brush Creek system station B2 was autotrophic with a low AI/ATP ratio (Table 79) suggesting a healthy association composed predominantly of algae. As show in Table 77 67 percent of the periphyton was algal biomass which was the highest of any station. At stations B3 and B4 the autotrophic index increased to 177 and 194 respectively, with corresponding increases in the AI/ATP ratios. This may suggest some inactive organic material when compared to station B6. At this latter station the community becomes more autotrophic (AI=123) with a slight increase in the AI/ATP ratio. This results from either a decrease in non-algal species, a decrease in non-living organic material, and an increase in ATP activity, or a combination of these aspects.

Most interesting is station B7 which had a high AI value of 187 yet had a low AI/ATP ratio similar to the autotrophic station B2. This indicates there was a high level of ATP suggesting living, active community with a large portion of non-algal biomass. There was approximately 34 percent algal biomass at this station (Table 77). At station B8 the AI was very high (530) as was the AI/ATP ratio. This indicates first a low level of algal biomass, which was true, i.e., 12 percent (Table 77), but also a high level of moribund or

non-living organic mass which would yield a low ATP level and a high ash-free dry weight value.

Non-algal Biomass/ATP ratio -
The ratio of non-algal biomass/ATP may give an indication of the condition or type of non-algal material, i.e., living or detrital. This is best seen when the ratios of the autotrophic index, organic weight/ATP, and non-algal biomass/ATP are compared side-by-side (Table 79).

Table 79. COMPARISON OF ORGANIC WEIGHT AND NON-ALGAL BIOMASS TO ATP AS RATIOS. IOWA ARMY AMMUNITION PLANT. BRUSH CREEK AND SPRING CREEK BURLINGTON, IOWA. MAY - JUNE 1975

Station	Autotrophic Index	AI/ATP	Organic Wt/ATP	Non-Algal Biomass/ATP
B1	188	-	-	-
B2	97	24	109	62
B3	177	47	123	98
B4	194	43	146	119
B5	-	-	50	-
B6	123	50	142	98
B7	187	27	97	79
B8	530	182	167	157
S1	63	26	115	-
S2	137	27	236	171

It is observed that parallel trends exist between stations B2, B3, and B4. As the autotrophic index increases, i.e., becomes more heterotrophic, likewise do the ratios of organic weight/ATP and non-algal biomass/ATP. This indicates an increase in non-algal biomass which is probably living material. At station B6 there was a decrease in the AI yet the organic weight/ATP ratio remained high and there was a slight decrease in the non-algal biomass/ATP ratio. This suggests

a community composed proportionally of more algae than the previous stations. Stations B2 and B6 had the highest biomass of algae (Table 77) and likewise have the lowest non-algal biomass/ATP ratios.

As the value of the organic weight/ATP ratio and the non-algal biomass/ATP ratio approach each other it suggests a large percentage of the ash-free dry weight (organic weight) is living and proportionally more heterotrophic. Furthermore, if the AI is greater than 100, it reflects a viable heterotrophic association. This is seen at station B7 (Table 79).

Greater differences between these two ratios accompanied by low AI values suggests a viable algae association. This is seen at station B2.

The other extreme is seen at station B8. High ratios of organic weight and non-algal biomass to ATP, accompanied by a very high AI value, suggest a heterotrophic community of low activity. It is probable that a large fraction of the ash-free dry weight is non-viable. The conversion of data indicates that about 88 percent of the periphyton at this station is non-algal (Table 77). Of this non-algal, organic mass most is probably non-living detrital, or moribund cells of heterotrophs.

At station S2 the AI indicates slight heterotrophism. The ratios of ATP suggest very low activity but also indicate that there may be a large fraction of non-living organic material (Table 79). The organic weight may represent a large portion of algae, algal biomass was 47 percent (Table 77) , and the non-algal biomass may be non-living, which would increase the AI value.

ATP/Organic Weight and ATP/Chlorophyll *a* -
One last comparison was to look as the levels of ATP/mg ash-free dry weight and ATP/mg chlorophyll *a*. The level of ATP decreased between

stations B2 and B4, although it was not a straight line decrease (Table 80). High ATP levels were reported at stations B5 and B7 with low values at stations B6 and B8. An increase in ATP levels was seen between stations S1 and S2.

When expressed as ATP/mg ash free dry weight there was a linear decrease between stations B2 and B4. Low ratios were also recorded at stations B6 and B8. Stations B5 and B7 had high levels ATP/mg ash-free dry weight (Table 80). Higher values indicates greater activity of the periphyton community. Low or decreasing levels would suggest a disproportionate increase in non-viable organic material, i.e. detritus, or the death of the existing community. Therefore, between stations B2 and B4 there was either an increase in non-living organic material or an inhibition and gradual decrease in biological activity of the periphyton microcommunity. The community was apparently stimulated at station B5, being viable with little non-living organic material. There was then a decrease in activity at station B6 followed by stimulation at station B7.

When expressed as ATP/mg chlorophyll a an indication of algal activity or condition is given. There appears to be a decrease in activity between stations B2 and B3 in terms of ATP/organic weight, i.e., 8.4×10^{-5} mg ATP/mg organic weight decreased to 6.6×10^{-5} mg ATP/mg organic weight. However, there was a corresponding shift of 8.1×10^{-3} mg/ATP mg chlorophyll a increasing to 11.7×10^{-3} mg ATP/mg chlorophyll a between stations B2 and B3 (Table 80). This suggests greater (increased) activity in the algal fraction of the periphyton community. The autotrophic index (Table 79) however, suggests a heterotrophic association. It may be concluded that the organic nature of the periphyton between these stations is possibly non-viable or detrital.

TABLE 80. COMPARISON OF ATP(mg) ORGANIC WEIGHT (mg) AND CHLOROPHYLL a (mg). IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS BURLINGTON, IOWA. MAY-JUNE, 1975.

Station	Org. Wt.	Chl. a	ATP	ATP/Org. Wt.	ATP/Chl. a
B1	7797	41.49	-	-	-
B2	2000	20.69	0.168	8.4×10^{-5}	8.1×10^{-3}
B3	1180	6.65	0.078	6.6×10^{-5}	11.7×10^{-3}
B4	2278	11.74	0.106	4.6×10^{-5}	9.0×10^{-3}
B5	607	-	0.240	39.5×10^{-5}	-
B6	1007	8.17	0.050	4.9×10^{-5}	6.1×10^{-3}
B7	2501	13.33	0.264	10.6×10^{-5}	19.8×10^{-3}
B8	451	0.85	0.016	3.5×10^{-5}	18.8×10^{-3}
S1	1209	19.24	0.091	7.5×10^{-5}	4.7×10^{-3}
S2	11564	84.32	0.208	1.8×10^{-5}	2.5×10^{-3}

Between stations B3 and B4 there was a decrease in the levels of ATP to both organic weight and chlorophyll a with a corresponding increase in the autotrophic index (Table 79 and 80). This suggests a decrease in the acitivity of the autotrophs as well as the heterotrophs and the possible increase in non-living material.

Increased levels were seen in both ratios between stations B6 and B7 (Table 80); ATP increased from 4.9×10^{-5} to 10.6×10^{-5} mg/mg ash-free dry weight and 6.1×10^{-3} to 19.8×10^{-3} mg/mg chlorophyll a. The autotrophic index increased from 123 to 187 (Table 79). This suggests a stimulation of both the heterotriphic and autotrophic franctions of the periphyton.

Definite conclusions are not readily evident in the comparisons of periphyton communities using ATP and other measurements. The trends of ATP, ash-free dry weight, and chlorophyll a were very similar. There did appear to be decreased activity at stations B3, B4, B6 and B8 of Brush Creek. Greatest activity of the periphyton micro-community was at station B2, B5, and B7 of Brush Creek. No consistent trend was observed between ATP and periphyton activity, and water and sediment chemistry.

Various ratios of organic biomass or chlorophyll to ATP were calculated in an effort to determine which periphyton fraction, i.e., algal or non-algal species, was most affected or caused the variations in ATP activity. Trends for the most part followed the autotrophic index. Although more comparisons and correlations can be applied to these data, time and space do not permit this effort. It may be worthwhile to apply a coefficient of correlation to these data.

In summary it can be said that ATP can be used to reflect the condition of a natural microcommunity. It also has the potential to define which level of organisms is most active and which is viable. Greatest difficulty in measuring ATP are the collection of material, preparation and handling, and extraction. In these experiments it is felt that only a small fraction of the ATP was extracted or recovered. ATP levels were low, consistently low yet constant, indicating a procedural or mathematical error. Additional time must be spent in reviewing all possible correlations of ATP data.

Results (October)

Species Occurrence -

Diatom dominance on artificial substrates (October) - The trend of diatom species diversity on artificial substrates for Brush and Spring Creeks showed an expected trend when effluents are present on a stream system. Table 81 and 82 and Figure 38 show the values of species diversity and evenness calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. The three samples collected at each station were very similar. This degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) At station B1 the diatom species distribution of the three replicates was similar above the 70 percent level (Figure 39). The mean species diversity of 3.01 was much higher this survey than during the spring, due to the samplers remaining in the water and thus allowing for better growth of periphyton.

2) The three replicates at station B2 were also similar above the 70 percent level (Figure 40). The mean species diversity was low (1.09).

3) Replication at station B3 was somewhat lower, however, the three replicates were similar above 65 percent (Figure 41). Mean species diversity was much lower than at station B2 (0.89).

4) The three replicate samples at station B4 were variable. Two replicates were similar above 85 percent while the third replicate was similar to these two only at the 55 percent level (Figure 42). Diversity was calculated at 0.84.

5) Sample replication at station B5 was good. The three samples were similar above .85 percent (Figure 43). Species diversity for the three combined replicates had increased to 1.23 from the previous station.

6) Similarity of the three replicates at station B6 varied. Two replicates were similar above 90 percent, while the third

Table 81. SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES.

IOWA ARMY AMMUNITON PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA

OCTOBER 1975

	Brush Creek								Spring Creek	
Sample Replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	3.05	0.84	0.85	0.92	1,28	0.55	1.67	2.46	2.23	2.65
2	3.00	1.00	0.95	0.74	1.20	1.28	1.97	2.20	2.50	2.88
3	2.99	1.42	0.87	0.87	1.22	0.63	2.25	2.31	2.31	2.62
$\overline{X}$	3.01	1.09	0.89	0.84	1.23	0.82	1.97	2.32	2.35	2.72
S^2	0.001	0.091	0.003	0.008	0.002	0.162	0.083	0.018	0.019	0.020
S	0.033	0.302	0.056	0.091	0.045	0.402	0.287	0.135	0.138	0.141

Table 82. SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. OCTOBER, 1975.

	Brush Creek								Spring Creek	
Sample Replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	0.85	0.33	0.44	0.44	0.50	0.22	0.63	0.69	0.67	0.76
2	0.86	0.40	0.46	0.30	0.55	0.47	0.71	0.68	0.70	0.80
3	0.82	0.48	0.42	0.40	0.63	0.25	0.75	0.66	0.66	0.73
$\overline{X}$	0.84	0.40	0.44	0.38	0.56	0.32	0.70	0.68	0.68	0.76
S^2	0.000	0.006	0.000	0.379	0.004	0.019	0.004	0.000	0.000	0.001
S	0.022	0.079	0.021	0.005	0.063	0.138	0.059	0.015	0.019	0.033

Figure 38. IAAP PERIPHYTON— DIVERSITY FOR ART. SUB. (OCT. 75)

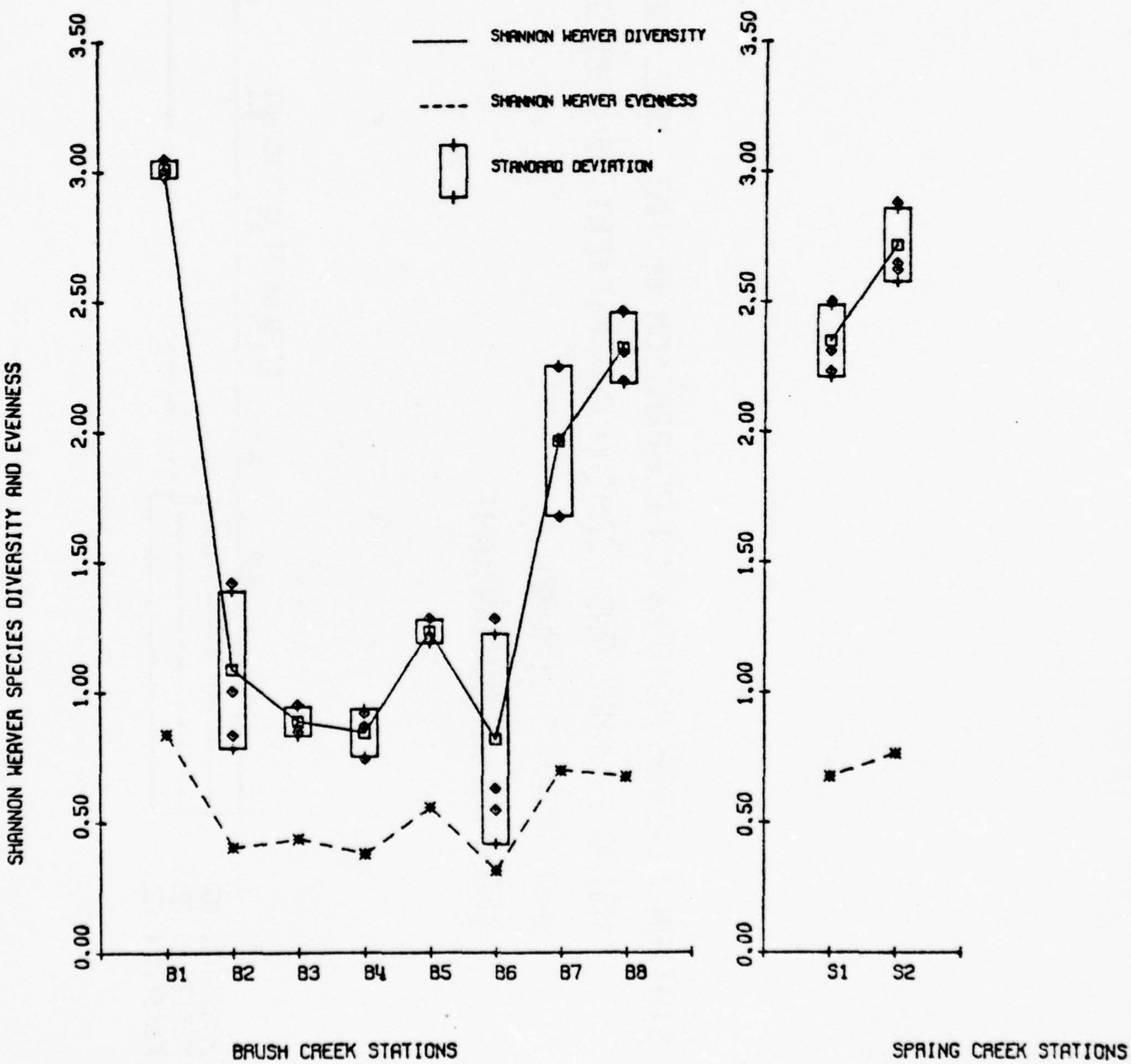


Figure 39.
STATION B1-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

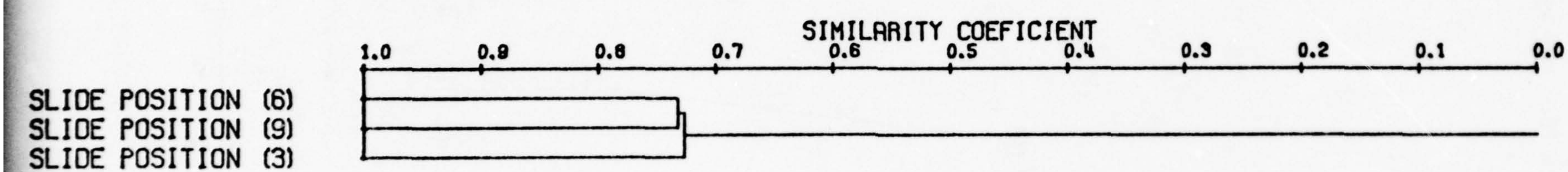


Figure 40.
STATION B2-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

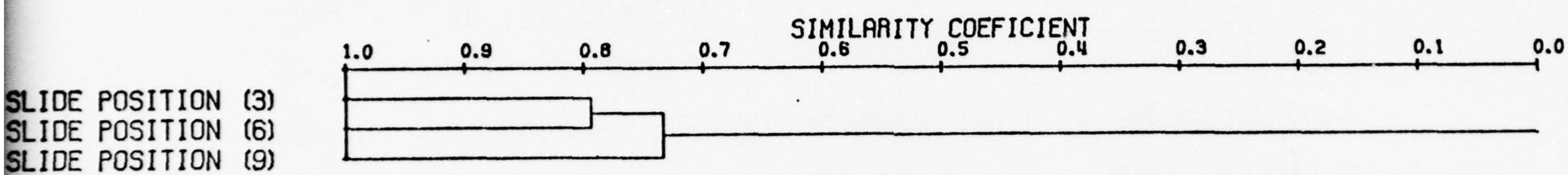


Figure 41.

STATION B3-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

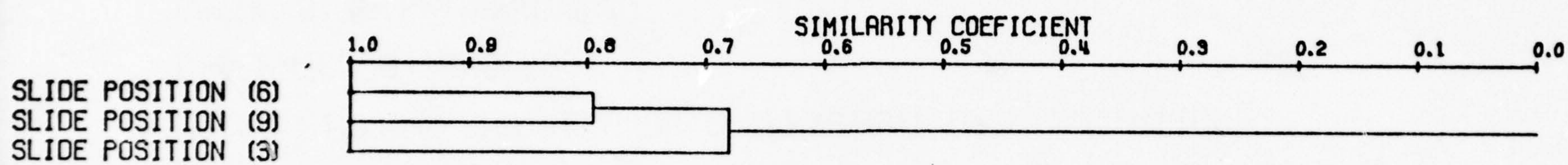


Figure 42.
STATION B4-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

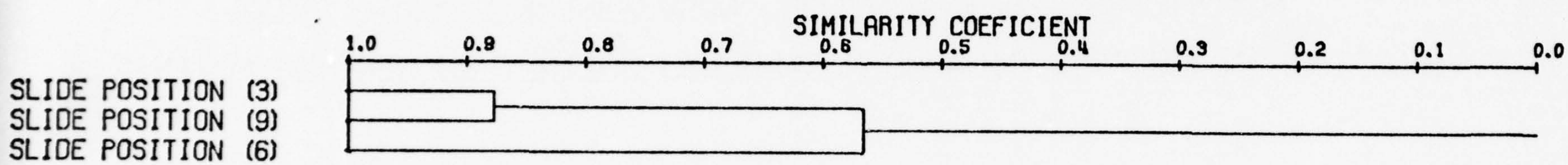


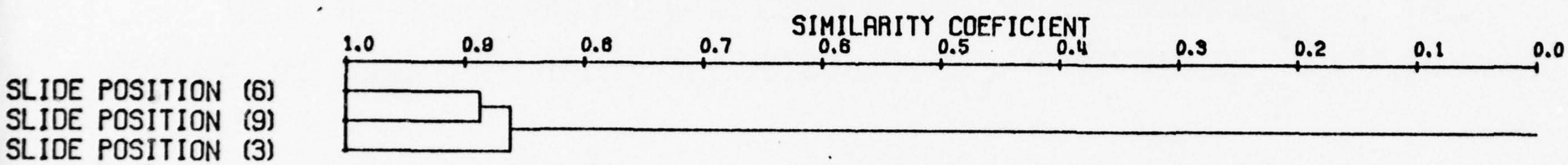
Figure 43.

STATION B5-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT



replicate was similar to these two at only 60 percent (Figure 44). Mean species diversity as this station decreased to 0.82.

7) At station B7 the mean diatom species diversity was 1.97, twice the level found at station B6. The three replicates were similar above 50 percent (Figure 45).

8) The three replicate samples at station B8 were similar above the 75 percent level (Figure 46). Species diversity was calculated at 2.32, the highest level of diversity since station B1 (3.01).

9) Both Spring Creek stations showed high mean diatom species diversities. Station S1 had a mean diatom species diversity of 2.35. Replication of the three slides was 70 percent (Figure 47).

10) Station S2 had its three replicates similar at 65 percent (Figure 48). Mean diatom species diversity for this station was 2.72.

Mean diatom species diversity of periphyton collected from artificial substrates decreased sharply from station B1 to station B2, and continued to decrease through stations B3 and B4 (Table 81; Figure 38). Species diversity then increased at station B5 and decreased again at station B6 to a level equal to that found at station B4. A sharp increase occurred between station B6 and station B8. Species evenness (Table 82; Figure 38) showed a parallel trend with species diversity.

Species diversity exhibited a small increase between stations S1 and S2 on Spring Creek (Table 81; Figure 38). Species evenness parallelled species diversity (Table 82; Figure 38).

Diatom species data from replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in four stations (S1, S2, B1 and B8) being grouped together which is a trend similar to that observed during the May-June collection period. Station S2 was similar to stations S1

Figure 44.

STATION B6-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

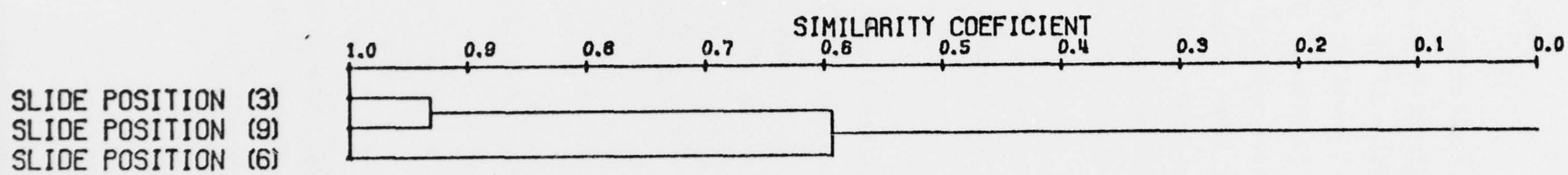


Figure 45.

STATION B7-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

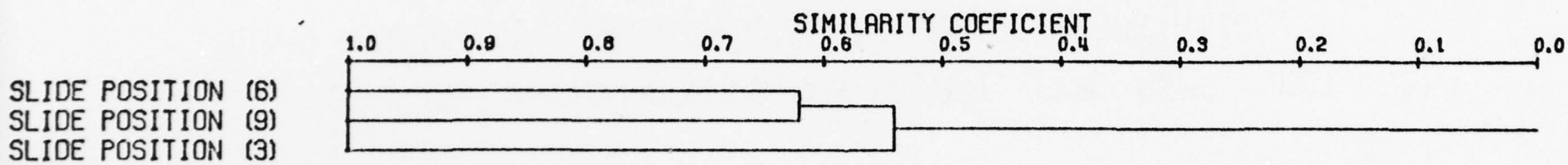


Figure 46.

STATION B8-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

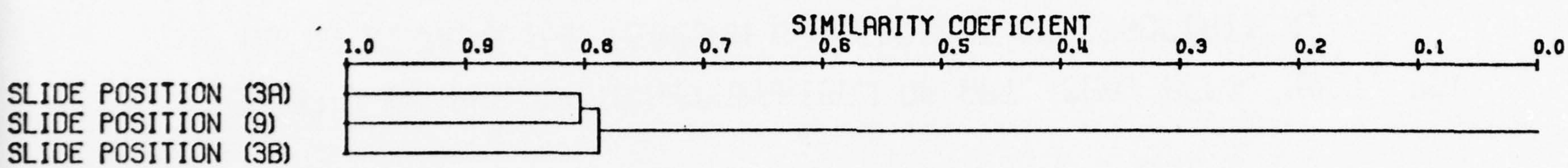


Figure 47.
STATION S1-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

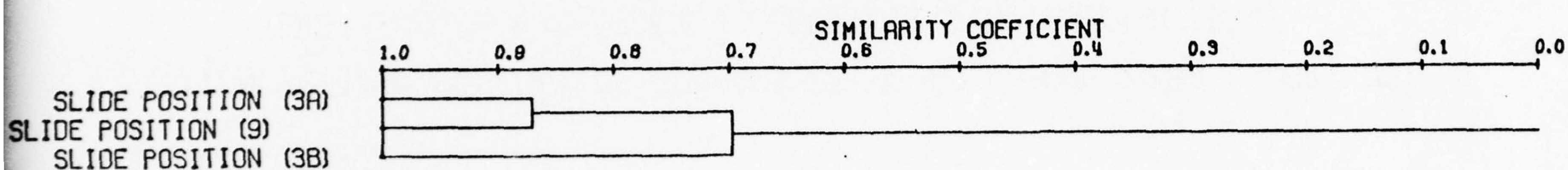
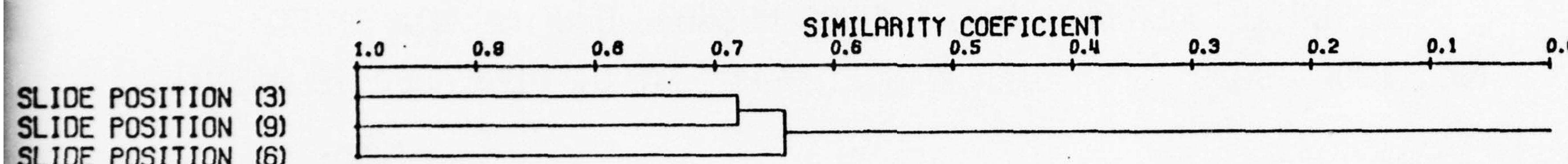


Figure 48.

STATION S2-IAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT. 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



and B1 at the 36 percent and 30 percent levels, respectively (Table 83; Figure 49). It was less similar to station B8 (23 percent). Station B8 had a very low similarity with station S1 (22 percent) while station B1 was similar to station B8 at only 17 percent. Station S1 and S2 of Spring Creek were expected to have a high similarity due to their proximate location in the same stream. Station B1 was also similar to these two Spring Creek stations, due to the fact that all three stations are in virgin waters with no industrial effluents to affect the diatom population. The fourth station, B8, was similar to the other station (i.e. S1, S2 and B1) at only 20 percent. Station B8 was the only station of the four affected by industrial effluents. These four stations had higher mean species diversity than the other stations.

Among the remaining stations, B2, B6 and B5 were similar at the 70 percent level. Station B2 and station B6 were the most similar of the three stations (77 percent). The B3 and B4 stations had diatom species associations similar at the 85 percent level. Both groups of stations (i.e. B2, B6, B5 vs B3, B4) were similar above the 60 percent level, with station B7 being similar to this combined group at 30 percent. All sampling stations were similar together at 14 percent. The lack of similarity at or with station B7 may be the result of its close proximity to the main domestic sewage treatment facility for the IAAP installation.

Application of the truncated normal curve[28] to the Brush Creek periphyton data revealed that the height of the mode was not exposed. Station B1 and B8 (Figure 50 and 57) of Brush Creek had their mode heights above six species, which is higher than any other station on the stream. Station B2 through B7 (Figures 51-56) had very low curves with the mode falling in the range of two to five species.

Table 83. COEFFICIENT OF ASSOCIATION COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED ARTIFICIAL SUBSTRATE REPLICATES AT EACH STATION.

IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS.

BURLINGTON, IOWA. OCTOBER 1975

	Brush Creek								Spring Creek	
Stations	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
B1	1.000									
B2	0.055	1.000								
B3	0.025	0.614	1.000							
B4	0.036	0.728	0.845	1.000						
B5	0.070	0.692	0.578	0.697	1.000					
B6	0.103	0.768	0.523	0.641	0.714	1.000				
B7	0.154	0.298	0.291	0.271	0.343	0.353	1.000			
B8	0.165	0.107	0.063	0.073	0.119	0.117	0.252	1.000		
S1	0.245	0.060	0.030	0.031	0.064	0.065	0.157	0.223	1.000	
S2	0.298	0.111	0.074	0.081	0.113	0.143	0.170	0.231	0.356	1.000

Figure 49.
IAAP PERIPHYTON-STATION COMPARISON OF ART. SUB.-COMBINED REP. (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

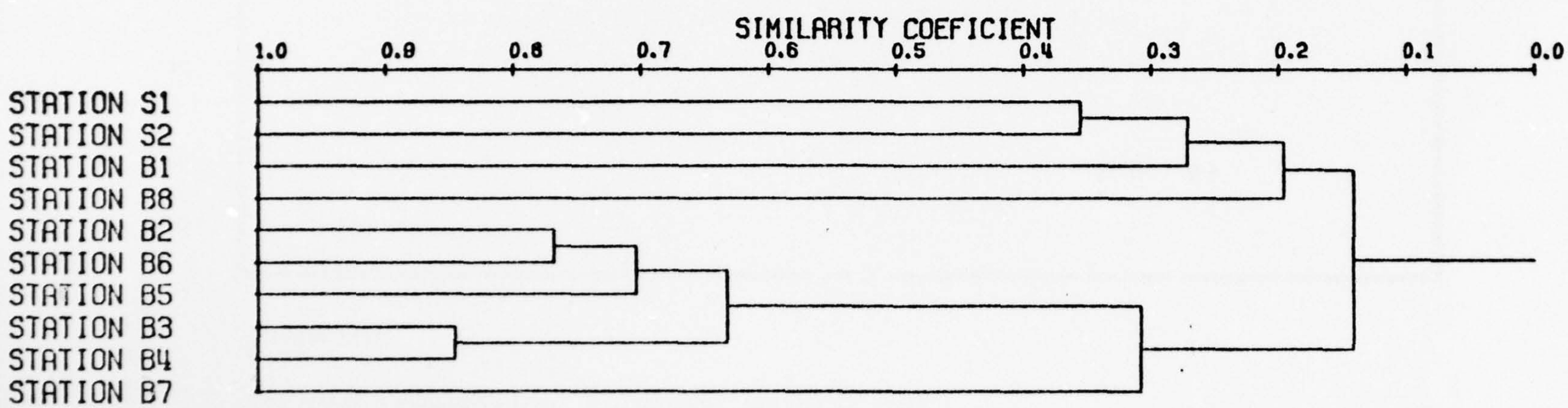


FIGURE 50. Distribution of Diatom Community Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

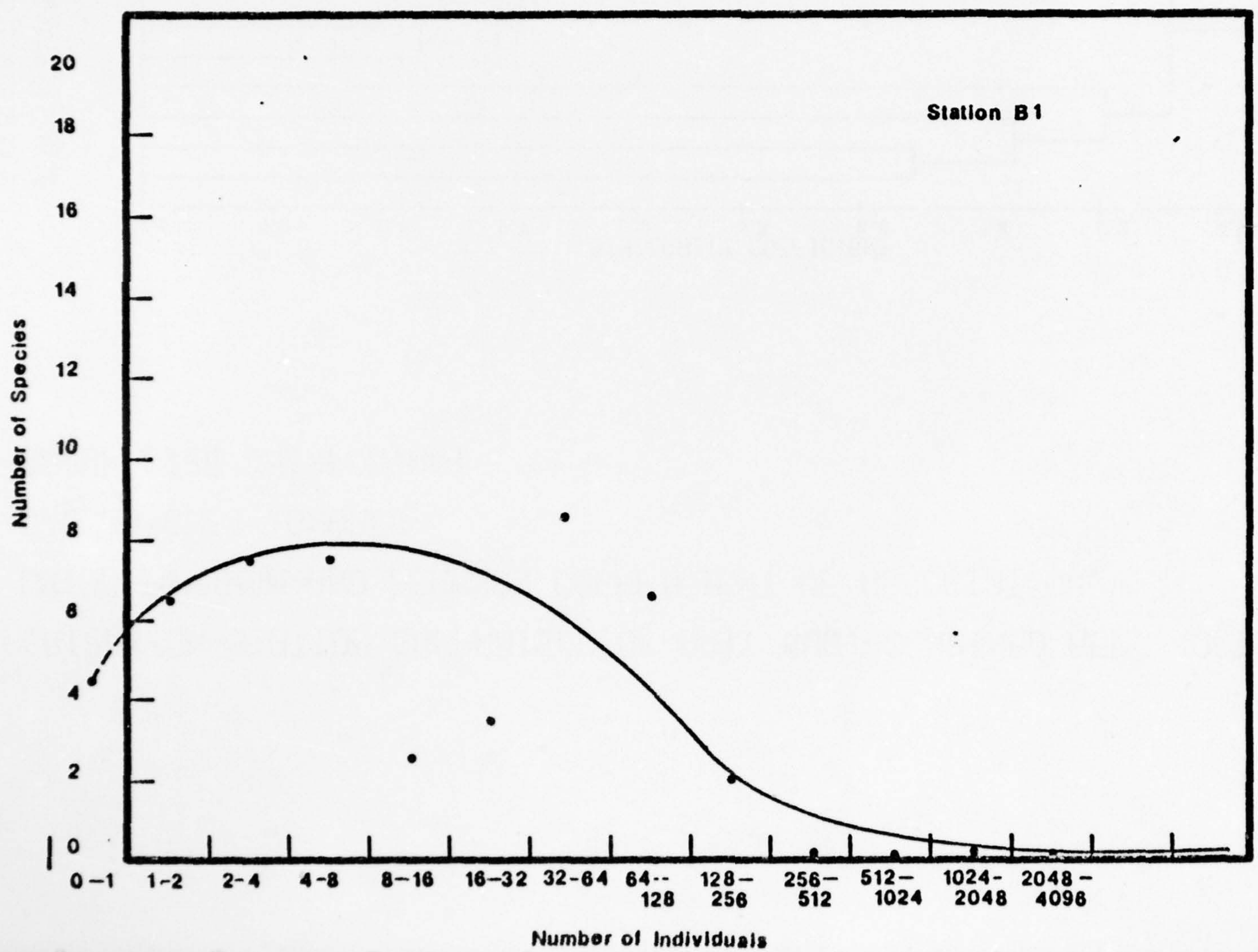


FIGURE 51. Distribution of Diatom Community Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

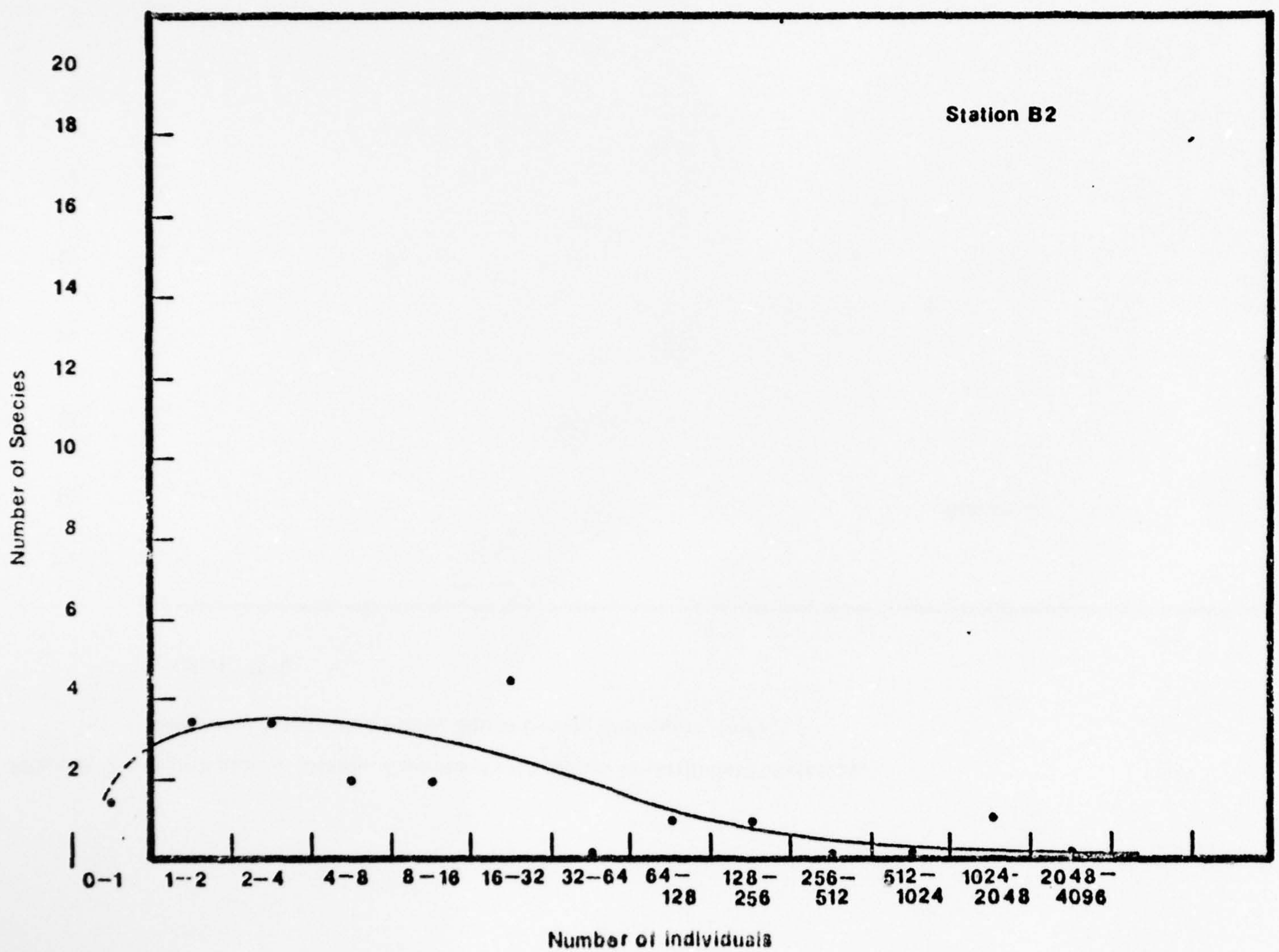


FIGURE 52. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

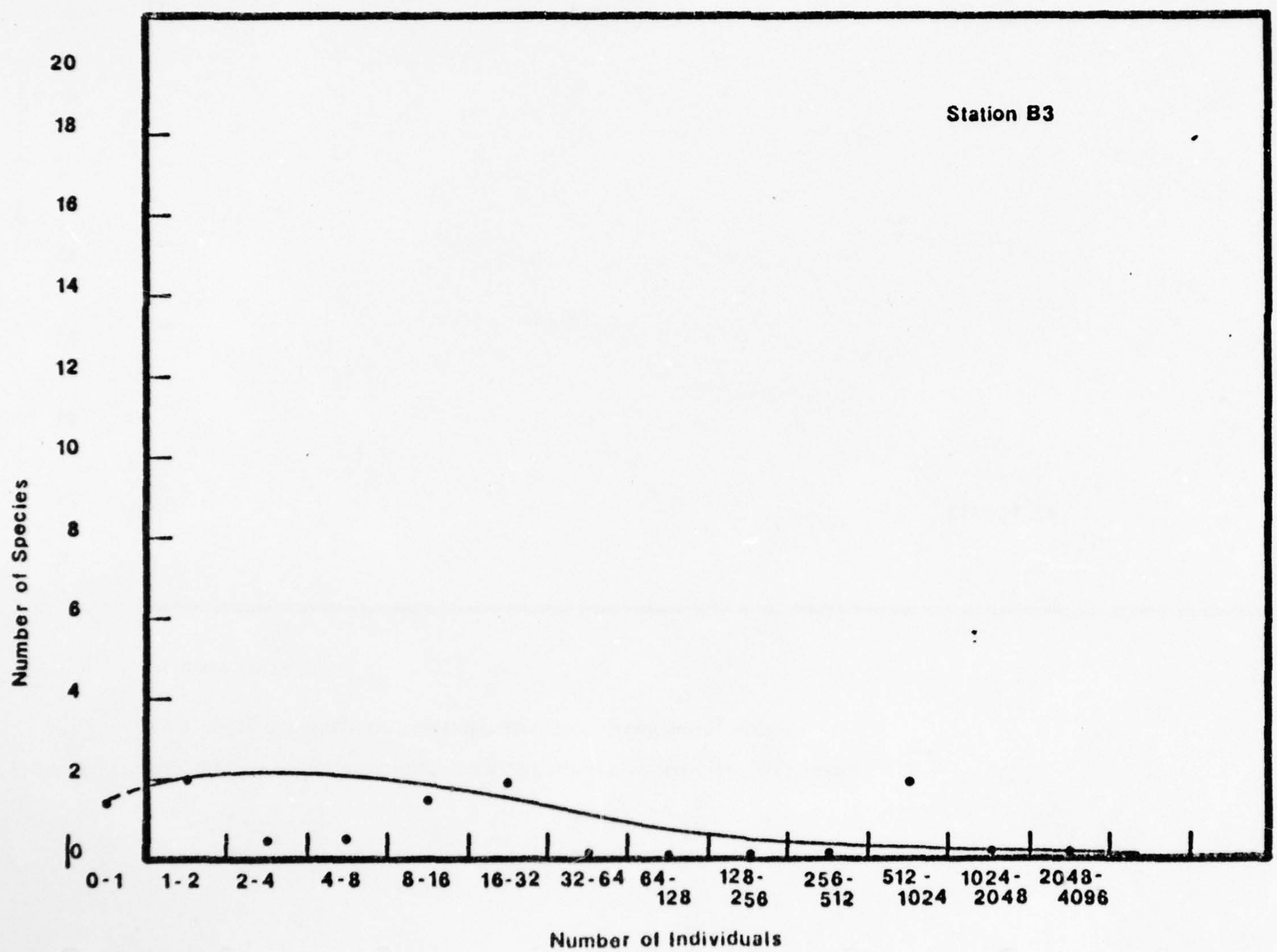


FIGURE 53. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

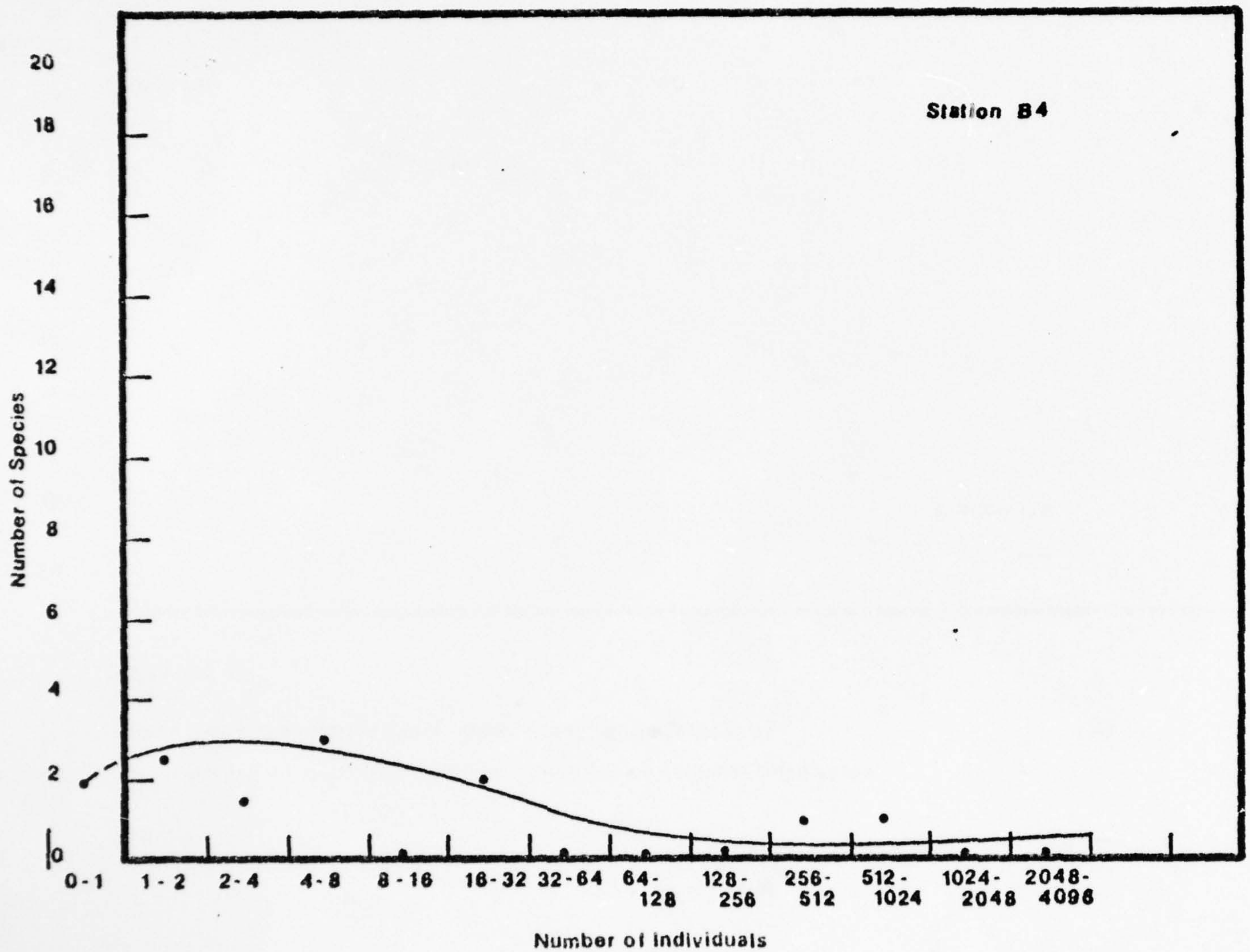


FIGURE 54. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

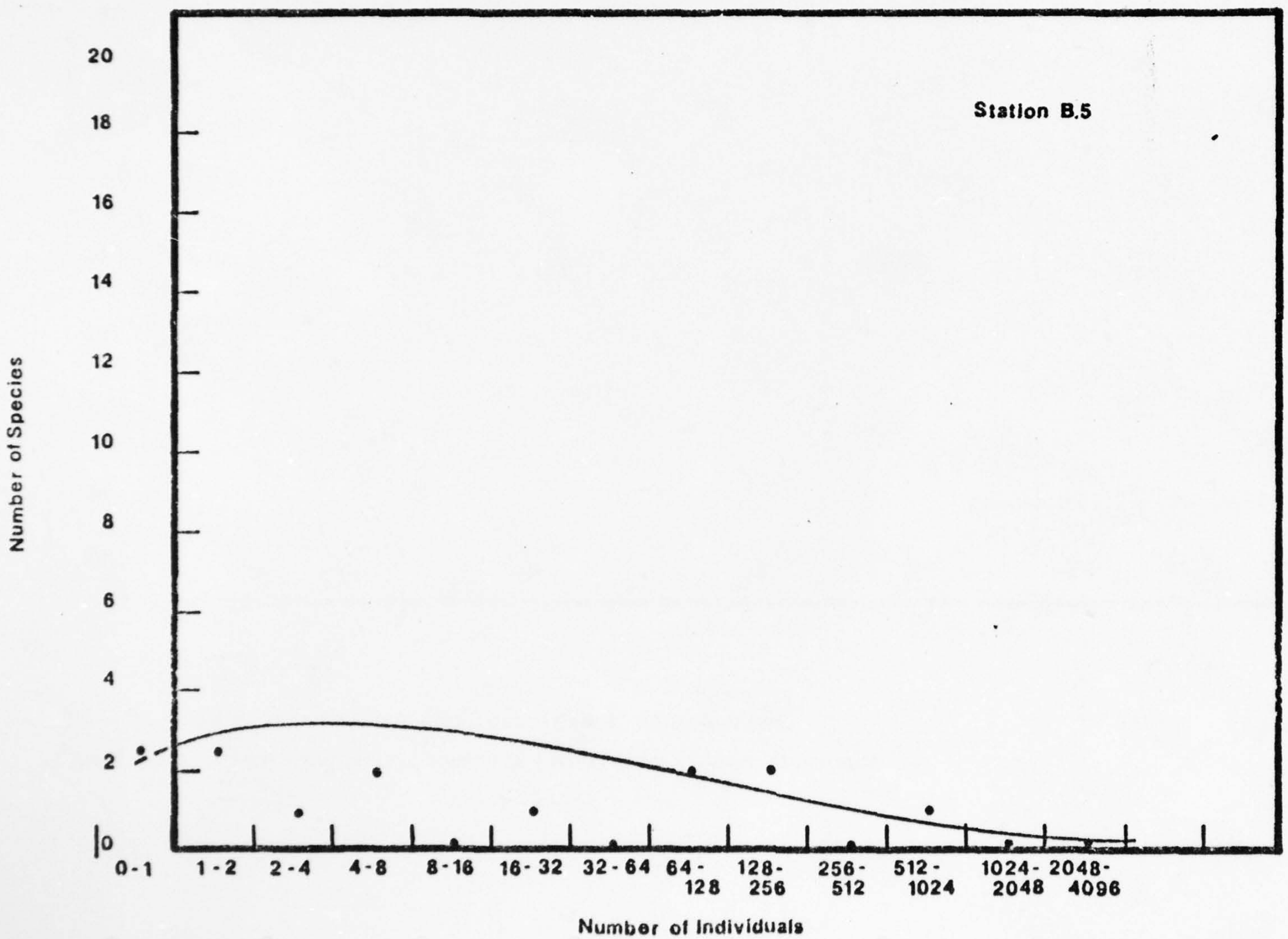
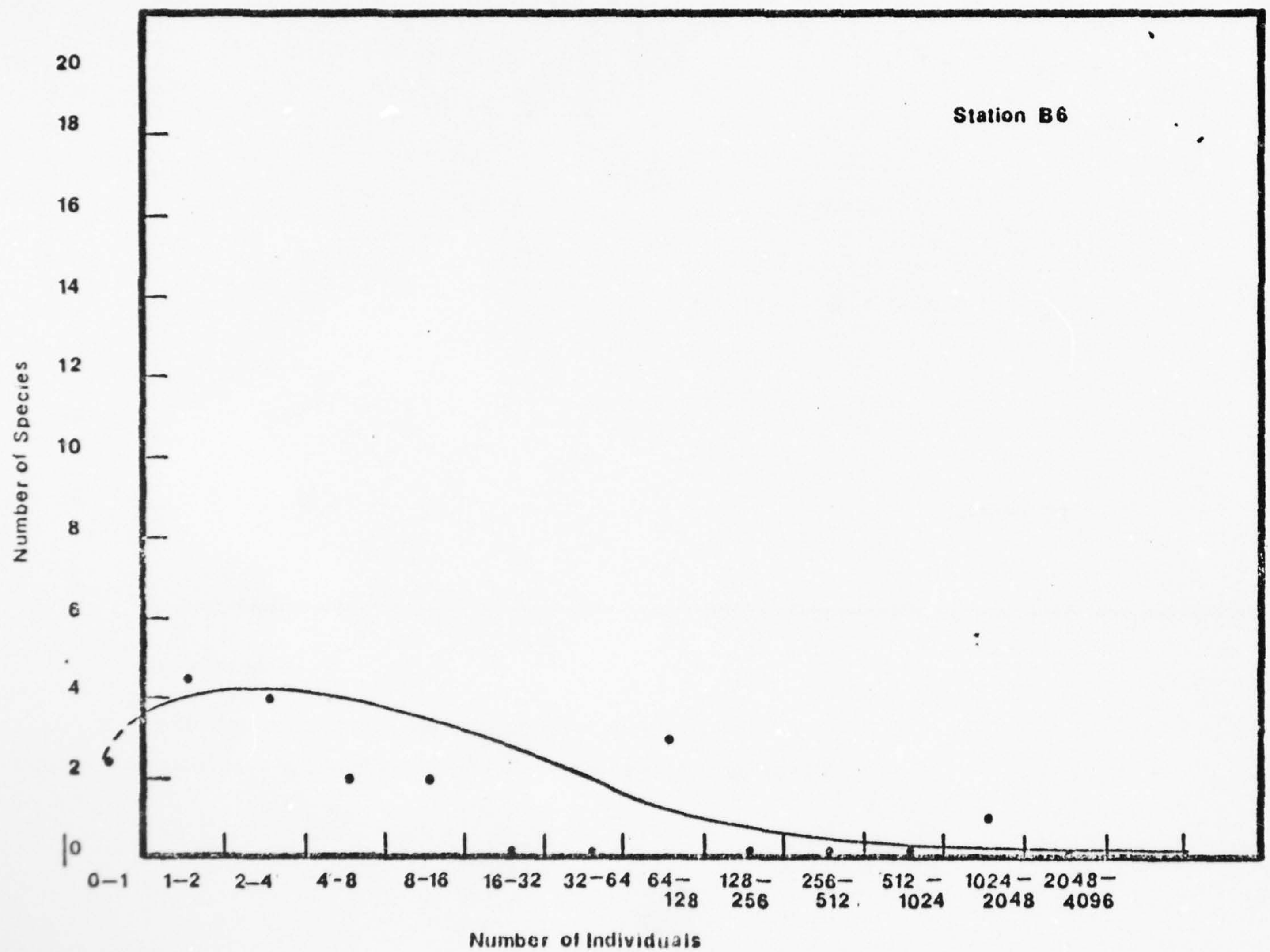


FIGURE 55. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

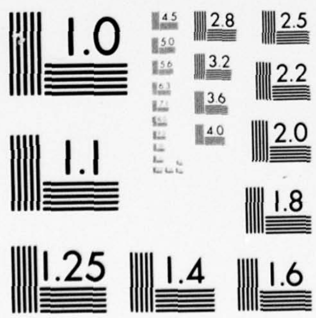
October 1975



AD-A036 776 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITI--ETC(U)
NOV 76 S L SANOCKI, P B SIMON, R L WEITZEL DAMD17-75-C-5046
UNCLASSIFIED NL

4 OF 5
AD
A036776

3677



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FIGURE 56. Distribution of Diatom Comunity Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek, Burlington, Iowa.

October 1975

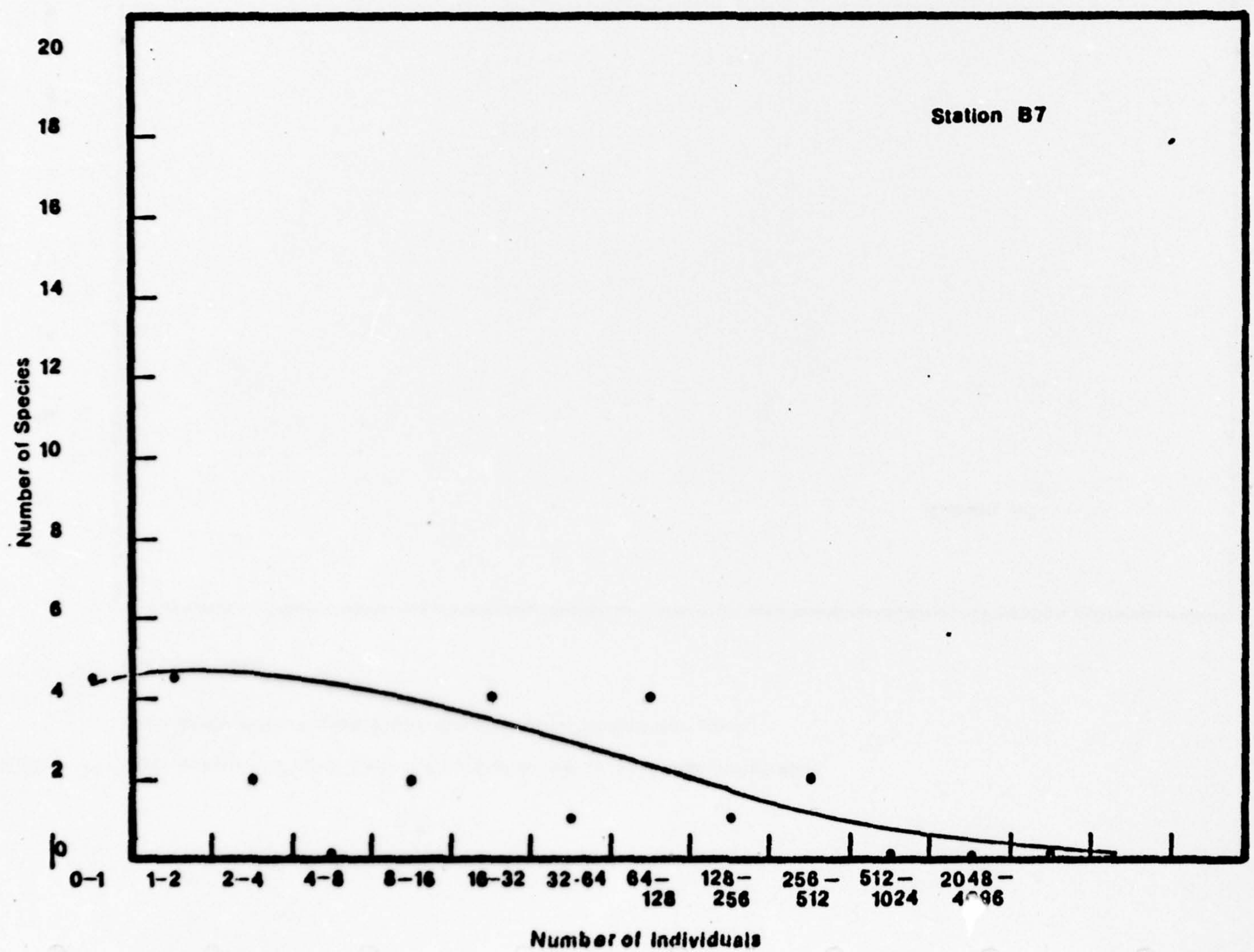
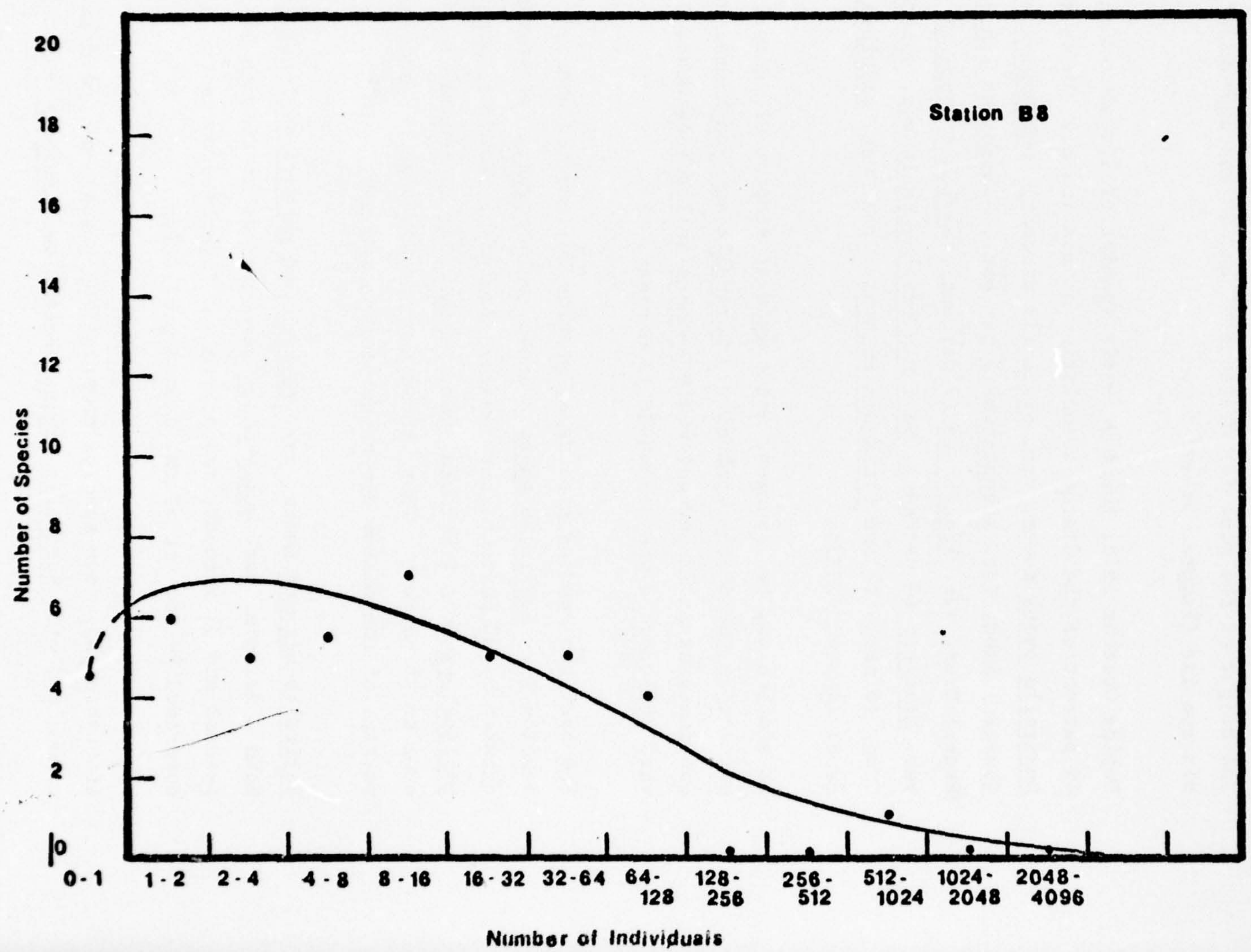


FIGURE 57. Distribution of Diatom Community Collected on Artificial Substrates.

Iowa Army Ammunition Plant, Brush Creek Burlington, Iowa.

October 1975



Station S1 and station S2 of Spring Creek had curves more like stations B1 and B8 of Brush Creek. Likewise, the coefficient of similarity (Figure 49) showed these stations to be most similar. The height of the mode for stations S1 and S2 was approximately six species (Figures 58 and 59).

During October 1975, there were six species of diatoms which comprised 49 percent of the diatom association at station B1. These were Surirella ovata Kuetz. var. ovata (17 percent), Gomphonema angustatum (Kuetz.) Rabh. var. angustatum (7 percent), Achnanthes lanceolata (Breb.) Grun. var. lanceolata (7 percent), Navicula heufleri Grun. var. heufleri (7 percent), Navicula cryptocephala var. veneta (Kuetz.) Grun. (6 percent) and Nitzschia amphibia Grun. var. amphibia (5 percent) (Appendix XIII).

At station B2, two species, not common at station B1, comprised 85 percent of the diatom community. Surirella angusta Kuetz. var. angusta was dominant at 72 percent while Amphora bullatoides Hohn. & Hellerm. var. bullatoides was common at 13 percent.

The same two species present at station B2 remained abundant at station B3. Surirella angusta Kuetz. var. angusta (61 percent) decreased by 11 percent, but remained dominant. However, Amphora bullatoides Hohn & Hellerm. var. bullatoides increased from 13 percent to 35 percent. Thus, these two species together comprised 96 percent of the diatom dominance at this station.

Surirella angusta Kuetz. var. angusta and Amphora bullatoides Hohn & Hellerm. var. bullatoides were present at station B4 at 63 percent and 31 percent, respectively. Together, these two species comprised 94 percent of the diatom population.

At station B5, four species comprised 93 percent of the diatom community, with Surirella angusta Kuetz. var. angusta remaining

FIGURE 58. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Spring Creek, Burlington, Iowa.

October 1975

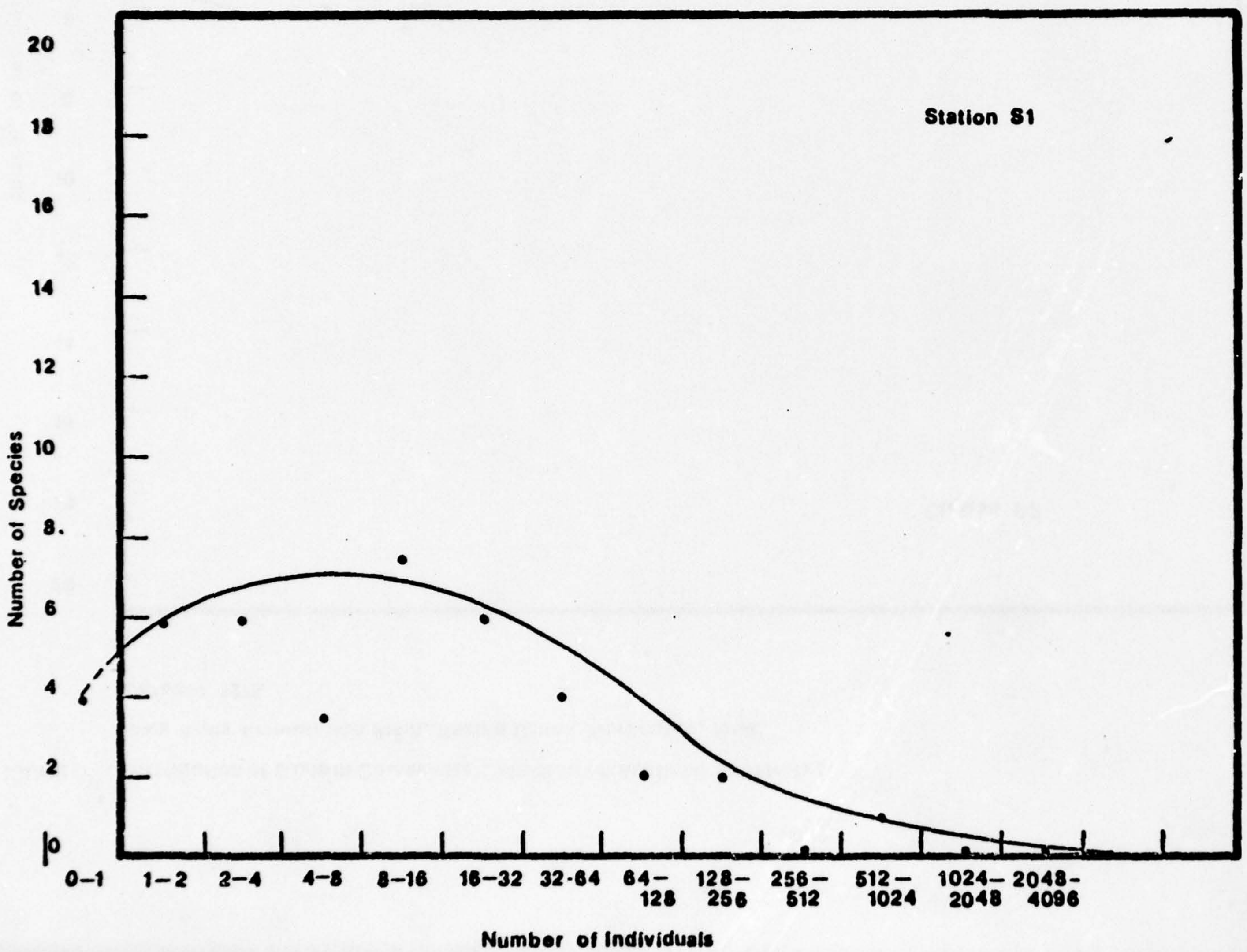
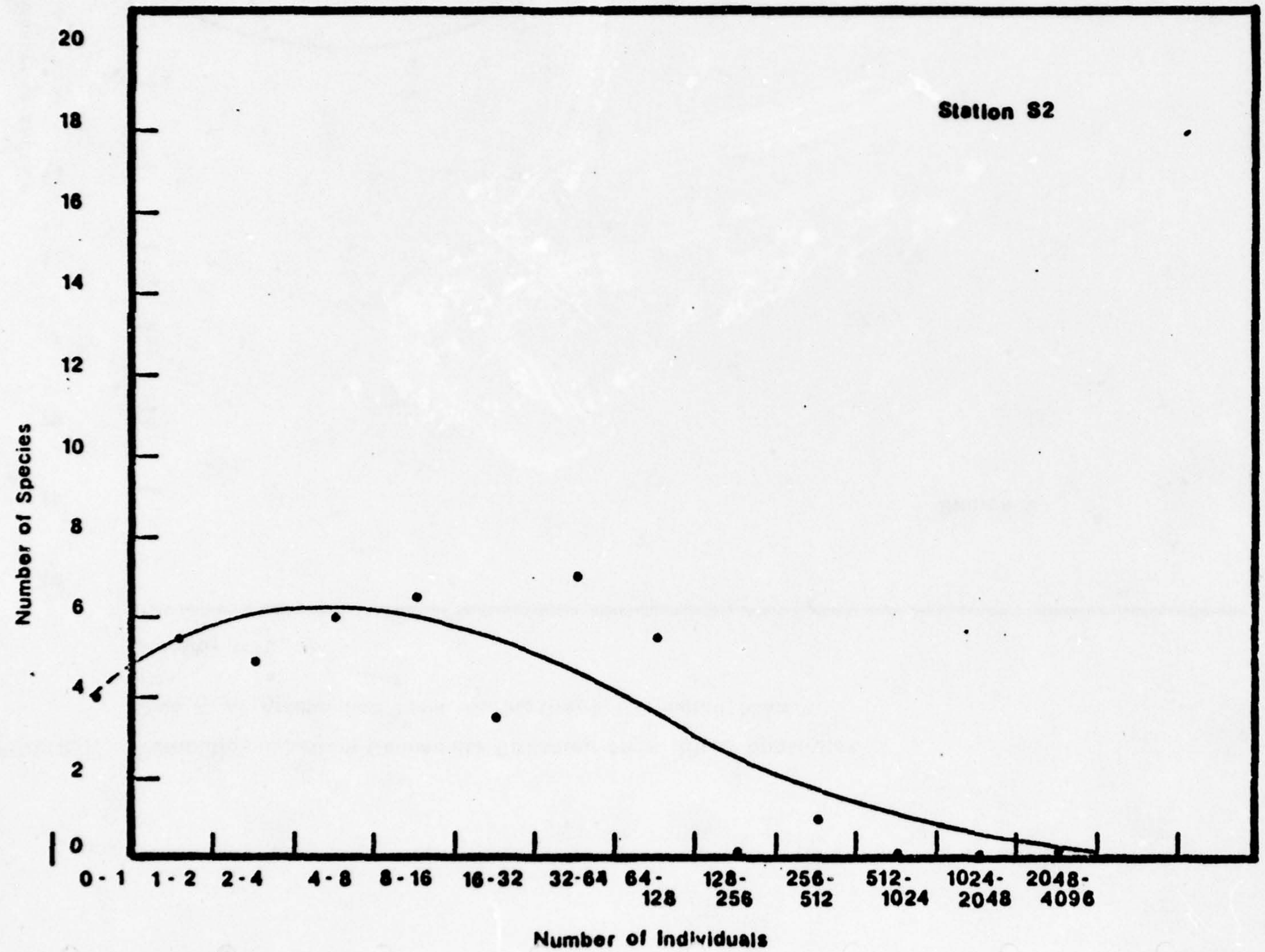


FIGURE 59. Distribution of Diatom Community Collected on Artificial Substrates.
Iowa Army Ammunition Plant, Spring Creek, Burlington, Iowa.
October 1975



dominant at 63 percent. Co-dominant was Achnanthes minutissima Kuetz. var. minutissma (13 percent). The two other species, Navicula biconica Patr. var. biconica and Amphora bullatoides Hohn & Hellerm. var. bullatoides, were common at 10 percent and 7 percent, respectively.

Three species at station B6 comprised 93 percent of the total diatom community structure. Surirella angusta Kuetz. var. angusta increased to 79 percent. Achnanthes lanceolata (Breb.) Grun. var. lanceolata and Amphora bullatoides Hohn & Hellerm. var. bullatoides were both common at 7 percent.

Surirella angusta Kuetz. var. angusta was dominant at station B7 but at a lower percent level (30 percent). Three other species, Gomphonema parvulum (Kuetz.) Grun. var. parvulum (25 percent), Achnanthes lanceolata (Breb.) Grun. var. lanceolata (10 percent) and Navicula pseudoatomus Lund var. pseudoatomus (8 percent) together comprised 43 percent of the diatom population at this station.

A new dominant, Navicula pseudoatomus Lund. var. pseudoatomus (44 percent), was present at station B8. Other species common and comprising 27 percent of the total population were Nitzschia fonticola Grun. var. fonticola (8 percent), Navicula viridula var. rostellata (Kuetz.) Cl. (8 percent), Amphora bullatoides Hohn. & Hellerm. var. bullatoides (6 percent) and Gomphonema parvulum (Kuetz.) Grun. var. parvulum (5 percent).

Spring Creek species occurrence showed different dominant species for each station. Station S1 had three species which comprised 62 percent of the diatom association Achnanthes lanceolata (Breb.) Grun. var. lanceolata was the dominant (38 percent). The two other species, Nitzschia amphibia Grun. var. amphibia and Nitzschia fonticola Grun. var. fonticola were both common at 12 percent.

At station S2, 61 percent of the diatom population was comprised of six species. Twenty-eight percent of the diatom association was Nitzshia amphibia Grun. var. amphibia, compared to 12 percent at station S1. Amphora bullatoides Hohn & Hellerm. var. bullatoides, Achnanthes lanceolata (Breb.) Grun. var. lanceolata, Gomphonema angustatum (Kuetz.) Rabh. var. angustatum, G. acuminatum var. coronata (Ehr.) W. Sm. and Surirella ovalis Breb. var. ovalis were next in decreasing order of abundance.

Differences in diatom community structure and similarity which occurred between the sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare species, each occurring at a level of between five and one percent or less than one percent, respectively. The occurence of common, very common, and abundant species remained somewhat constant throughout the station scheme. Most often the same species fell into these categories with slight shifts seen between their relative frequencies. To summarize Appendix XIII total number of taxa at the reference and recovery stations, i.e. B1, S1, S2, B8, was higher, ranging from 42 to 46 taxa. The Brush Creek stations between B1 and B8 had a very low number of taxa (10-25 species).

Diatom dominance on natural substrates (October) - Samples collected from natural substrates included growths on wood, rock and sediment surfaces. Tables 84 and 85 and Figure 60 show the values of species diversity and evenness for each station, respectively, as well as the mean and standard deviation for these values. Diversity based on combined species data from the three substrate types is also included in Table 84. The combined species diversity is more representative of the periphyton community occurring at the different stations because these are not true replicate samples, being from different substrate types.

Table 84 . SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS BURLINGTON, IOWA OCTOBER 1975

	Brush Creek								Spring Creek	
Sample Type	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Wood	*	1.53	1.40	1.15	1.85	2.17	1.96	2.71	2.72	2.63
Rock	*	1.83	0.86	1.02	1.04	1.23	2.29	1.09	2.91	2.55
Sediment	3.26	1.14	2.19	0.95	0.65	0.95	1.79	2.81	2.91	2.23
$\overline{X}$	3.26	1.50	1.48	1.04	1.18	1.45	2.01	2.20	2.85	2.47
S^2	0.0	0.12	0.45	0.01	0.37	0.41	0.06	0.92	0.01	0.05
S	0.0	0.35	0.67	0.10	0.61	0.64	0.25	0.96	0.11	0.21
Combined Diversity	3.26	1.72	1.95	1.09	1.38	1.61	1.20	2.84	3.29	2.93

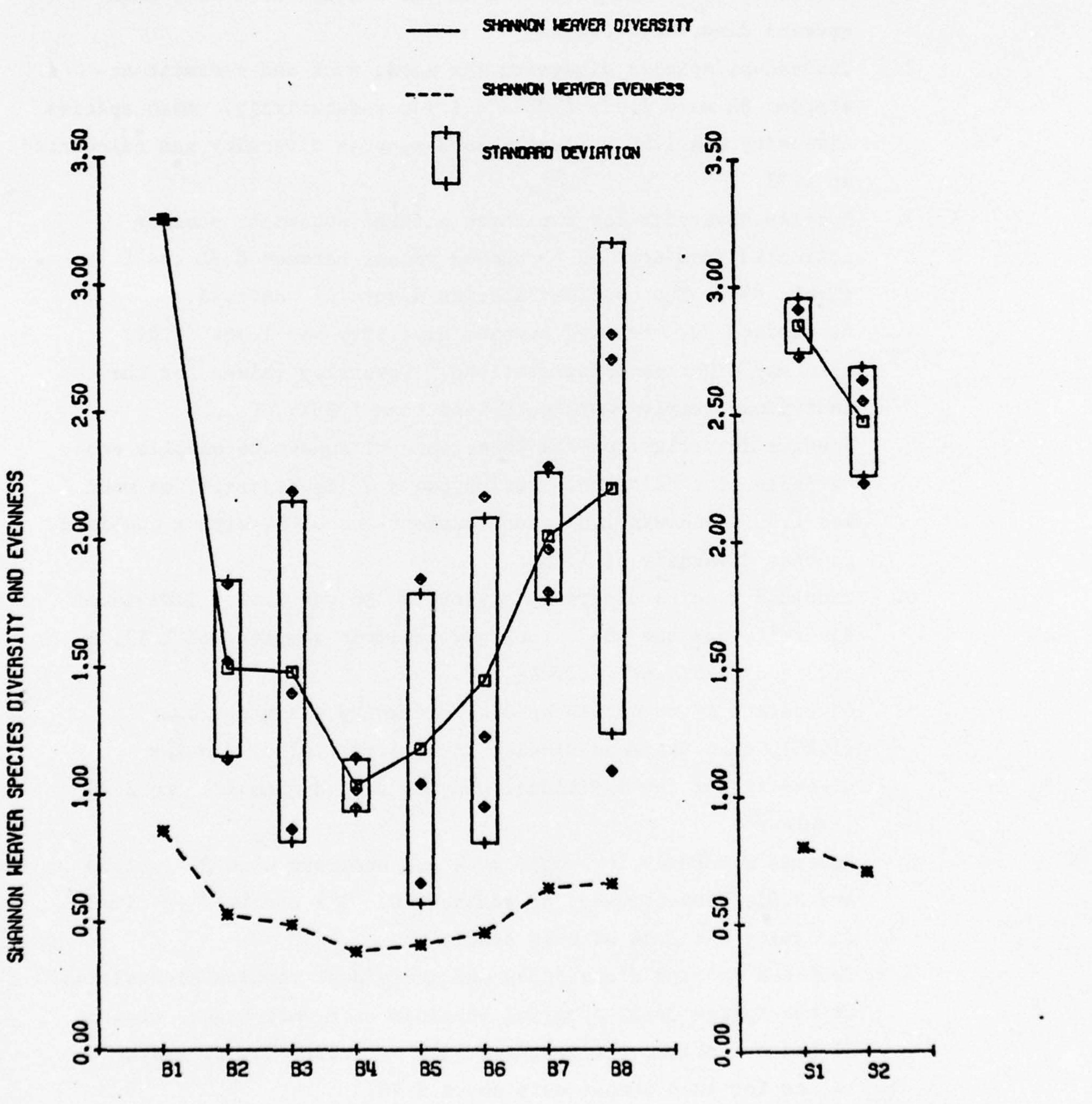
* Due to substrate limitation, no samples were collected.

Table 85 . SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS BURLINGTON, IOWA. OCTOBER 1975

	Brush Creek								Spring Creek	
Sample Type	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Wood	*	0.52	0.48	0.40	0.62	0.63	0.66	0.78	0.79	0.78
Rock	*	0.63	0.33	0.39	0.33	0.42	0.69	0.39	0.83	0.67
Sediment	0.86	0.44	0.66	0.37	0.28	0.32	0.55	0.80	0.78	0.66
$\overline{X}$	0.86	0.53	0.49	0.38	0.41	0.46	0.63	0.65	0.80	0.70
S^2	0.0	0.01	0.03	0.00	0.03	0.02	0.005	0.05	0.001	0.004
S	0.0	0.10	0.16	0.01	0.18	0.16	0.07	0.23	0.03	0.07

* Due to substrate limitations, no samples were collected.

Figure 60.
IAAP PERIPHYTON- DIVERSITY FOR NAT. SUB. (OCT 75)



Using the combined species diversity values the following were noted:

1. At station B1, natural substrate collections were limited to the sediment sample. The stream at this time was dry because of the drought conditions. This one sample had a very high species diversity (3.26).
2. Individual species diversity for wood, rock and sediment at station B2 were 1.53, 1.83 and 1.14, respectively. Mean species diversity was 1.50 while combined species diversity was calculated at 1.72.
3. Species diversity for the three natural substrate samples collected from station B3 showed values between 0.86 and 2.19 (Table 84). The combined species diversity was 1.95.
4. At station B4, combined species diversity was lower (1.09) than any other sampling stations. Diversity values for the individual samples were each less than 1.20.
5. Species diversity for the three natural substrate samples was variable at station B5. Periphyton species diversity on wood was 1.85, rock was 1.04, and sediment was 0.65, with a combined species diversity of 1.38.
6. Combined species diversity at station B6 was 1.61. Individual diversity for the wood, rock and sediment samples was 2.17, 1.23 and 0.95, respectively.
7. At station B7, combined species diversity was much lower (1.20), than the mean species diversity (2.01). Species diversity for the individual samples ranged from 1.79 to 2.29 (Table 84).
8. Species diversity for wood, rock and sediment were 2.71, 1.09 and 2.81, respectively, at station B8. The combined species diversity was 2.84 at this station.
9. Combined species diversities and individual species diversities at the Spring Creek sampling stations were very high. Station S1 had a combined species diversity of 3.29. The diversity values for each sample were above 2.70.

10. At station S2, individual species diversity for each substrate was very close, ranging from 2.23 to 2.63. The combined species diversity was 2.93.

Mean diatom species diversity of periphyton collected from the three natural substrates showed a sharp decrease between station B1 (3.26) and station B2 (1.50) (Table 84; Figure 60). Station B3 remained at the same diversity level as station B2. From station B3 to station B4, a decrease occurred (1.48 to 1.04). An increase occurred from station B4 through B8. At Spring Creek, a decrease was seen between station S1 and station S2.

The combined species diversity trend, which is more representative of the diatom community collected from the natural substrates, was very different from the mean species diversity. A sharp decrease occurred between stations B1 (3.26) and B2 (1.72) with a small increase to station B3 (1.95). A decrease was then seen between station B3 and station B4. From station B4 an increase in diversity occurred to station B6 where it then decreased at station B7. Between stations B7 and B8 a sharp decrease occurred. A decrease occurred between the Spring Creek stations, S1 and S2, but at higher values than mean species diversity.

Diatom species data from the three natural substrates were combined and compared between stations using the coefficient of similarity. The applicaton of the Pinkham and Pearson coefficient of associaton resulted in seven Brush Creek stations being similar. These were stations B2, B3, B4, B5, B6, B7 and B8 (Table 86 ; Figure 61). Each station also had lower combined species diversity than stations B1, S1 and S2. Stations B2 and B4 were most similar at 76 percent. Stations B5, B6, B7, B3 and B8 followed in decreasing similarity as shown on Figure 61. All seven stations were similar to each other above the 55 percent level.

Station B1 and station S1, which had the highest species diversity, were paired when using the coefficient of similarity. They were similar

Table 86. COEFFICIENT OF ASSOCIATION COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATES AT EACH STATION.

IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS
BURLINGTON, IOWA OCTOBER 1975

	Brush Creek								Spring Creek	
Stations	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
B1	1.000									
B2	0.550	1.000								
B3	0.491	0.678	1.000							
B4	0.541	0.757	0.657	1.000						
B5	0.511	0.662	0.612	0.687	1.000					
B6	0.493	0.661	0.625	0.672	0.671	1.000				
B7	0.544	0.684	0.640	0.659	0.655	0.640	1.000			
B8	0.443	0.598	0.621	0.545	0.495	0.504	0.590	1.000		
S1	0.495	0.427	0.466	0.428	0.397	0.407	0.503	0.492	1.000	
S2	0.388	0.425	0.439	0.429	0.369	0.422	0.449	0.397	0.481	1.000

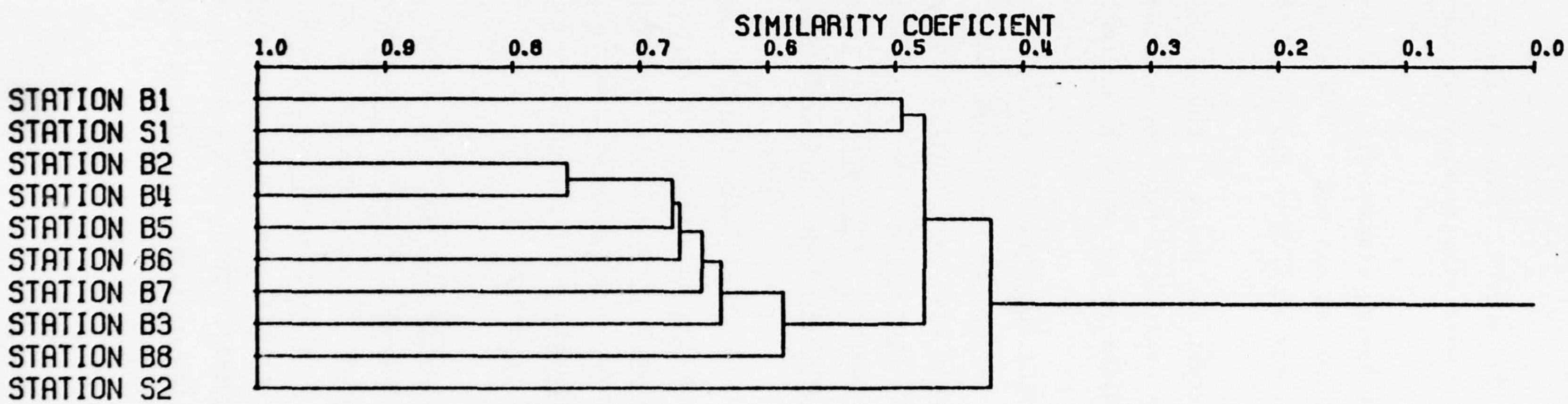
Figure 61.

IAAP PERIPHYTON-STATION COMPARISON OF NATURAL SUBSTRATES (OCT. 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



at 50 percent. Station groups - B2, B3, B4, B5, B6, B7, B8, - and - B1, S1 - were similar above 45 percent.

The Spring Creek station S2 was the least similar to all other stations, however it had one of the highest species diversities (2.93). This station, S2, was similar to the other nine stations near the 40 percent level.

Percent dominance of the diatom species occurring on natural substrates was calculated from the species list in Appendix XIV. This was very similar to the species dominance found on the artificial substrates.

During October 1975, there were five species of diatoms which comprised 40 percent of the diatom association at station B1. These were Surirella ovalis Breb. var. ovalis (16 percent), Achnanthes lanceolata (Breb.) Grun. var. lanceolata (7 percent), Navicula cincta (Ehr .) Ralfs, var. cincta (6 percent), Surirella angusta Kuetz. var. angusta (6 percent) and Nitzschia palea (Kuetz.) W. Sm. var. palea (5 percent) (Appendix XIV).

At station B2, four species comprised 90 percent of the diatom community. Surirella angusta Kuetz. var. angusta was dominant at 37 percent while Navicula pygmaea Kuetz. var. pygmaea was a co-dominant (30 percent). The two other species were Amphora bullatoides Hohn & Hellerm. var. bullatoides (12 percent) and Navicula pseudoatomus Lund. var. pseudoatomus (11 percent).

Surirella angusta Kuetz. var. angusta remained dominant (47 percent) at station B3. Navicula pseudoatomus Lund. var. pseudoatomus increased in frequency from 11 percent to 18 percent and was co-dominant. Also common at this station were Amphora bullatoides Hohn. & Hellerm. var. bullatoides (9 percent) and Achnanthes minutissima Kuetz. var. minutissima (6 percent). Thus, these four species together comprised 96 percent of the diatom dominance on natural substrates during October.

Two species comprised 88 percent of the total diatom population at station B4. These were Surirella angusta Kuetz. var. angusta and Amphora bullatoides Hohn. & Hellerm. var. bullatoides at 69 percent and 19 percent respectively.

At station B5, three species occurred together at 84 percent of the diatom community, with Surirella angusta Kuetz. var. angusta remaining dominant at 68 percent. Amphora bullatoides Hohn. & Hellerm. var. bullatoides and Navicula seminulum var. hustedtii Patr. were both common at 8 percent.

Similar to station B4, station B6 had the same two species present and comprising 75 percent of the diatom population. Surirella angusta Kuetz. var. angusta decreased slightly from 68 percent to 61 percent, while Amphora bullatoides Hohn. & Hellerm. var. bullatoides increased from 8 percent to 14 percent.

Surirella angusta Kuetz. var. angusta was dominant at station B7 but at a lower percent level (33 percent). Three other species, Navicula pseudoatomus Lund. var. pseudoatomus (25 percent), Rhoicosphenia curvata (Kuetz.) Grun. var. curvata(8 percent) and Achnanthes lanceolata (Breb.) Grun. var. lanceolata (6 percent) together comprised 39 percent of the diatom population at this station.

At station B8, Surirella ovalis Breb. var. ovalis recurred at 8 percent but was not dominant as at station B1. Surirella angusta Kuetz. var. angusta was dominant (24 percent). Other species common were Navicula pseudoatomus Lund. var. pseudoatomus (12 percent) and Amphora bullatoides Hohn. & Hellerm. var. bullatoides (11 percent). Thus, four species comprised 55 percent of the diatom association.

Spring Creek species occurrence showed different dominant species for each station. Station S1 had five species which comprised 43 percent of the diatom population. A new dominant, Nitzschia amphibia Grun. var. amphibia was present at 14 percent. Rhoicosphenia curvata (Kuetz.) Grun. var. curvata (8 percent), Surirella angusta Kuetz. var. angusta

(8 percent), Navicula heufleri var. leptocephala (Breb. ex Grun.) Patr. comb. nov. (7 percent) and Surirella ovalis Breb. var. ovalis (6 percent) were common.

At station S2, 53 percent of the diatom community was comprised of four species. Seventeen percent of the diatom association was Surirella ovalis Breb. var. ovalis, compared to 6 percent at station S1. Navicula minima Grun. var. minima, Nitzschia amphibia Grun. var. amphibia and Achnanthes minutissima Kuetz. var. minutissima were next in decreasing order.

Differences in diatom community structure and similarity which occurred between the sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare species, each occurring at a level of between five and one percent or less than one percent, respectively. Some stations in the relative frequency of occurrence of common, very common, and abundant species appear to be significant at several stations. To summarize Appendix XIV. The reference station on Brush Creek, B1, and the recovery station, B8, had a high total number of species, 45 and 49, respectively. The remaining Brush Creek stations had a total number of taxa ranging from 25 to 39. The Spring Creek stations, S1 and S2 both had 57 taxa.

Ash-Free Dry Weight -
A comparison of ash-free dry weight (mg/m^2 and mg/m^2/day) during October 1975 showed a similar trend to May-June 1975. A decrease in ash-free dry weight occurred between station B1 and station B4 (Table 87 and 88; Figure 62). Station B1 had the highest ash-free dry weight value 232.91 mg/m^2/day) while station B4 showed the lowest value of ash free dry weight (64.92 mg/m^2/day). Station B5 increased slightly in ash-free dry weight, with stations B6 and B7 remaining at a similar level. A sharp increase occurred between station B7 and station B8 from 75.08 mg/m^2/day to 203.01 mg/m^2/day.

Table 87. PERIPHYTON ASH-FREE DRY WEIGHT (mg/m^2).
IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK,
BURLINGTON, IOWA. OCTOBER 1975

	Brush Creek								Spring Creek	
Slide position in artificial substrate sampler	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide	1721.52	4810.13	5924.05	2582.28	1544.30	1468.35	3417.72	7645.57	1594.94	5367.09
Slide	8607.59	6126.58	2278.48	1493.67	3012.66	2278.48	1670.89	6278.48	1949.37	5873.42
Slide	11746.84	3012.66	3088.61	1392.40	3164.56	3063.29	2607.59	7392.40	NS*	8075.95
Slide	7772.15	6405.06	5443.04	3620.25	2708.86	2531.64	3291.14	NS	NS	5873.42
Slide	9746.84	5037.97	2582.28	NS	2126.58	3468.35	2151.90	NS	NS	4531.64
x	7918.99	5078.48	3863.29	2272.15	2511.39	2562.02	2627.85	7105.48	1772.16	5944.30
s^2	1.42×10^7	1799898.29	2873770.08	1097848.47	450059.72	587534.41	551639.89	528974.65	62810.31	1720689.83
s	3771.53	1341.603	1695.22	1047.78	670.86	766.508	742.72	727.31	250.62	1311.75

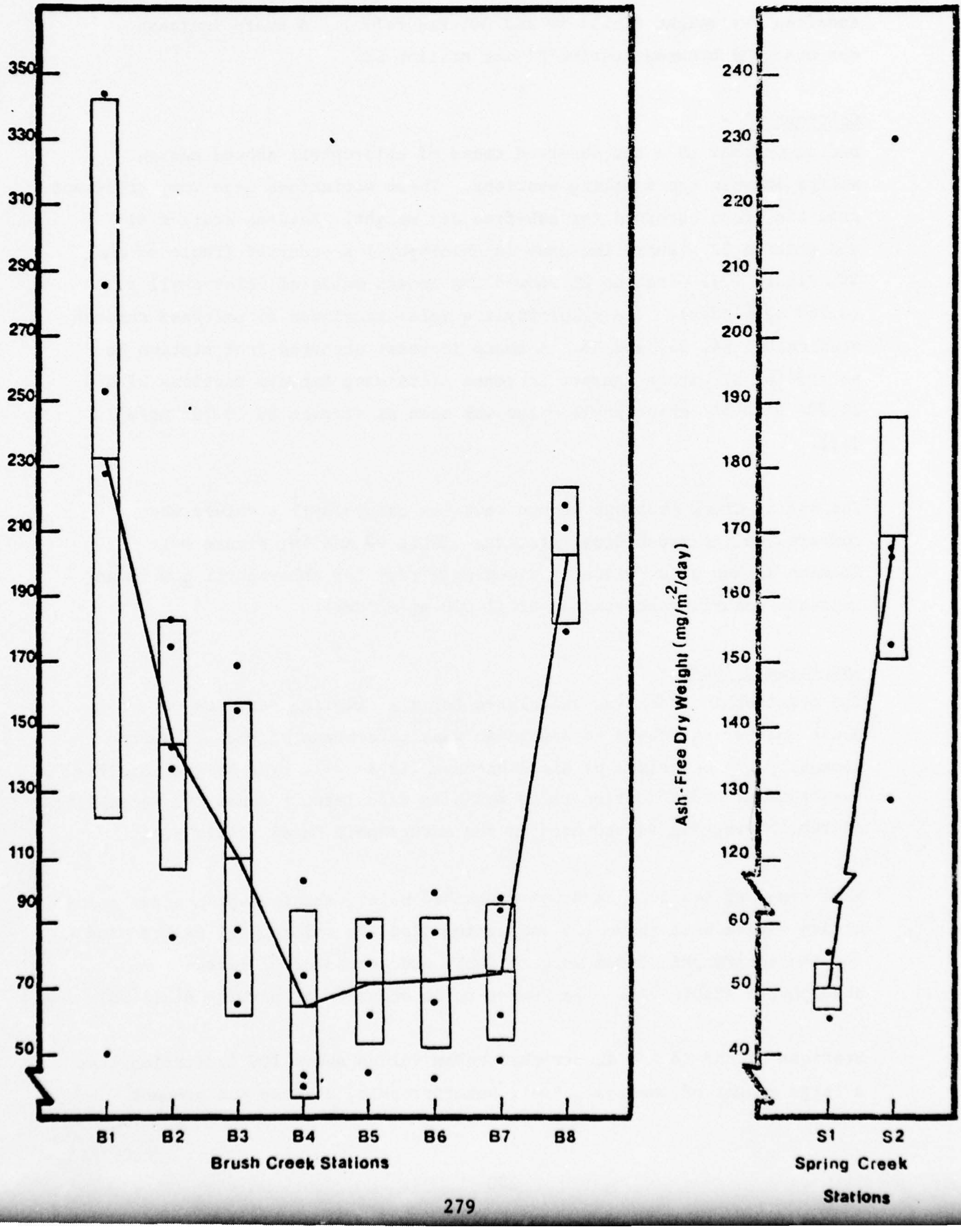
*NS = no sample - slide lost

Table 88 PERIPHYTON ASH-FREE DRY WEIGHT (mg/m^2/day).
IOWA ARMY AMMUNITION PLANT; BRUSH AND SPRING CREEK.
BURLINGTON, IOWA. OCTOBER 1975

	Brush Creek								Spring Creek	
Slide position in artificial substrate sampler	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide	50.63	137.43	169.26	73.78	44.12	41.95	97.65	218.44	45.57	153.34
Slide	253.16	175.04	65.10	42.68	86.08	65.10	47.74	179.39	55.70	167.81
Slide	345.50	86.08	88.25	39.78	90.42	87.52	74.50	211.21	NS*	230.74
Slide	228.59	183.00	155.52	103.44	77.40	72.33	94.03	NS	NS	166.78
Slide	286.67	143.94	73.78	NS	60.76	99.10	61.48	NS	NS	129.48
Number of days	34	35	35	35	35	35	35	35	35	35
x	232.91	145.10	110.38	64.92	71.76	73.20	75.08	203.01	50.64	169.63
s^2	12305.34	1469.09	2346.01	896.31	367.51	479.70	450.32	431.62	51.31	1405.81
s	110.93	38.33	48.44	29.94	19.17	21.90	21.22	20.78	7.16	37.494

*NS = no sample - slide lost

FIGURE 62. Periphyton Ash-Free Dry Weight (mg/m²/day) from Five Replicate Artificial Substrates. Iowa Army Ammunition Plant, Brush and Spring Creek, Burlington, Iowa.
October 1975



At Spring Creek, station S1 showed a low value of 50.64 $mg/m^2/day$ for ash-free dry weight (Table 87 and 88; Figure 62). A sharp increase was observed between station S1 and station S2.

Chlorophyll -

During October 1975 the observed trend of chlorophyll showed marked shifts between the sampling stations. These variations were very different from the trend observed for ash-free dry weight. Between station B1 and station B2 a sharp increase in chlorophyll a occurred (Table 89 and 90; Figure 63). Station B1 showed the lowest value of chlorophyll a (0.167 $mg/m^2/day$). The chlorophyll a value continued to decrease through station B3, B4, B5, and B6. A sharp increase occurred from station B6 to station B7 with a sharper increase continuing between stations B7 and B8. The highest chlorophyll value was seen at station B8 (3.782 $mg/m^2/day$).

The Spring Creek stations showed very low chlorophyll a values when compared to the Brush Creek stations (Table 89 and 90; Figure 63). Station S1 had a low value of 0.068 $mg/m^2/day$ for chlorophyll a with an increase occurring at station S2 (1.070 $mg/m^2/day$).

Autotrophic Index -

The autotrophic index was caluclated for all sampling stations on Brush and Spring Creeks to determine what percentage of the periphyton community was comprised of algal biomass (Table 91). The before acidification:after acidification ratio was also calculated to show the reliability of the chlorophyll values used in the autotrophic index (Table 92).

Most sampling stations on Brush Creek had before acidification:after acidification ratios well above 1.5 indicating that the chlorophyll values used for the autotrophic index were reliable and consisted of little phaeophytin (Table 92). The lowest ratio occurred at station B1 (1.55).

Stations B1 and B6 had autotrophic index values above 100 indicating that a large amount of nonalgal, i.e., heterotrophic, biomass was present

Table 89. PERIPHYTON CHLOROPHYLL a (mg/m^2). IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK. BURLINGTON, IOWA. OCTOBER, 1975

Slide position in artificial substrate sampler	Station									
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 1	6.35	71.55	29.74	51.53	18.75	12.26	44.85	155.76	2.89	41.83
Slide 4	4.91	73.43	77.89	35.73	17.37	9.94	35.48	107.04	1.96	34.15
Slide 7	3.42	92.99	65.29	7.48	62.06	32.48	9.34	134.38	2.34	59.01
Slide 10	2.81	44.20	78.37	70.35	37.05	24.28	75.95	NS*	NS	37.90
Slide 13	11.82	36.50	42.238	NS	24.00	33.96	14.08	NS	NS	14.49
Number of days	35	35	35	35	35	35	35	35	35	35
x	5.86	63.73	58.7	41.2	31.8	22.5	35.9	132.3	2.39	37.4
s^2	10.3	426.8	381.5	530.9	276.3	99.3	573.2	397.7	0.146	204.4
s	32.2	20.6	19.5	23.04	16.6	9.96	23.9	19.9	0.382	14.2

*NS = no sample - slide lost

Table 90. PERIPHYTON CHLOROPHYLL a (mg/m^2/day). IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK BURLINGTON, IOWA. OCTOBER 1975

Slide position in sampler	Station B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 1	0.18	2.04	0.85	1.47	0.54	0.35	1.28	4.45	0.08	1.20
Slide 4	0.14	2.10	2.22	1.02	0.50	0.28	1.01	3.06	0.07	0.98
Slide 7	0.10	2.66	1.86	0.21	1.77	0.93	0.27	3.84	0.07	1.69
Slide 10	0.08	1.26	2.24	2.01	1.06	0.69	2.17	NS*	NS	1.08
Slide 13	0.34	1.04	1.21	NS	0.69	0.97	0.40	NS	NS	0.41
Number of days	35	35	35	35	35	35	35	35	35	35
$\bar{x}$	0.167	1.821	1.677	1.179	0.909	0.645	1.026	3.782	0.068	1.070
s^2	.008	0.348	0.311	0.433	0.225	0.081	0.467	0.324	0.0001	0.166
s	0.092	0.590	0.558	0.658	0.475	0.284	0.684	0.569	0.011	0.408

*NS = no sample - slide lost

FIGURE 63. Periphyton Chlorophyll a (mg/m²/day) from Five Replicate Artificial Substrates. Iowa Army Ammunition Plant, Brush and Spring Creek, Burlington, Iowa.

October 1975

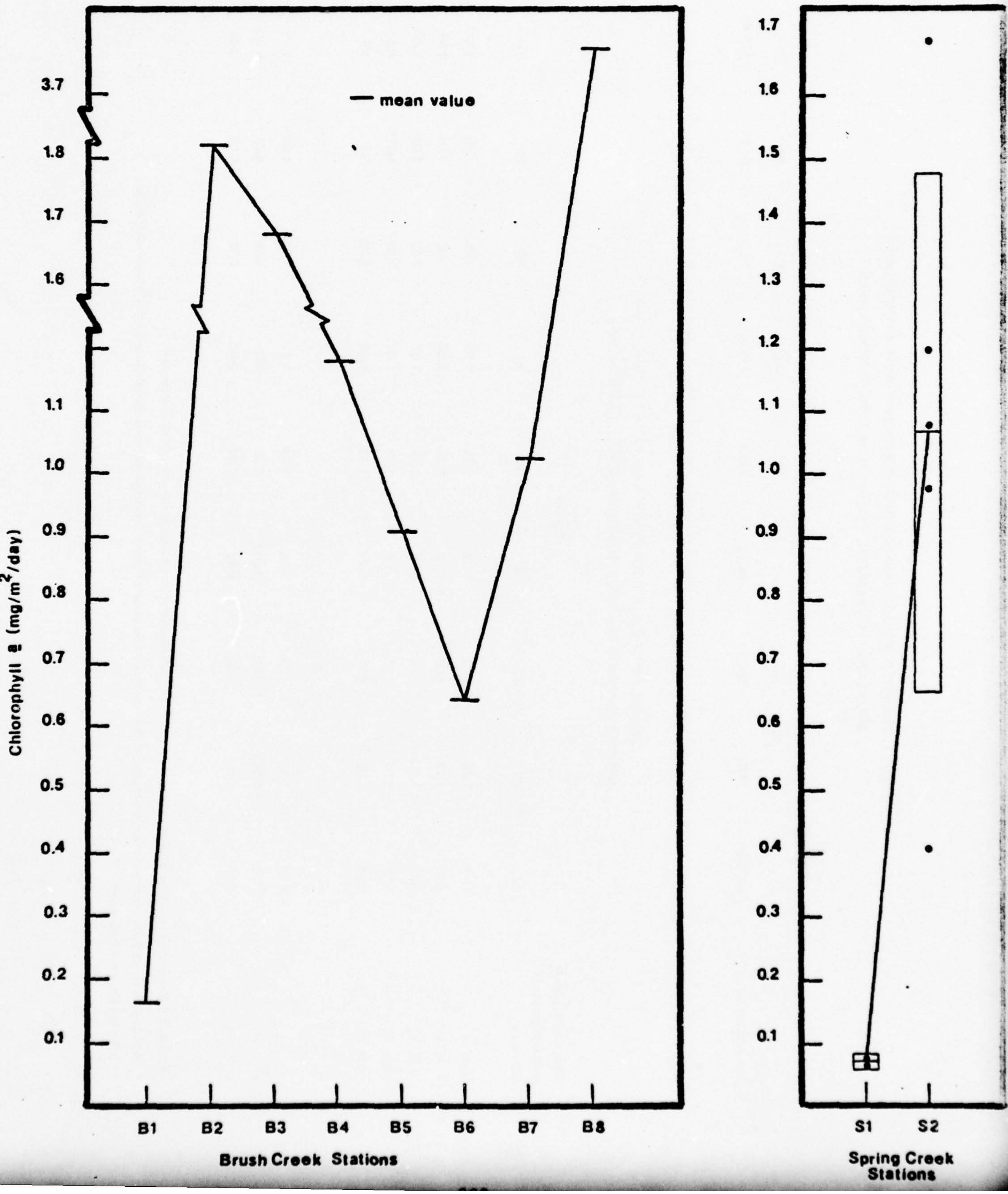


Table 91. PERIPHYTON AUTOTROPHIC INDEX. IOWA ARMY AMMUNITION PLANT, BRUSH AND SPRING CREEK, BURLINGTON, IOWA OCTOBER 1975

	Station									
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Autotrophic Index*	1351.36	79.69	65.81	55.14	78.97	113.87	73.20	53.71	741.48	158.94

Table 92. BEFORE ACIDIFICATION:AFTER ACIDIFICATION RATIO. BRUSH AND SPRING CREEKS, BURLINGTON, IOWA. OCTOBER 1975

Slide position in artificial substrate sampler	Station									
	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
Slide 1	1.50	1.60	1.72	1.68	1.76	1.78	1.68	1.58	1.60	1.55
Slide 4	1.84	1.75	1.66	1.79	1.70	1.68	1.68	1.64	1.57	1.59
Slide 7	1.46	1.62	1.79	1.71	1.74	1.62	1.62	1.63	1.60	1.56
Slide 10	1.38	1.71	1.75	1.80	1.74	1.84	1.68	NS**	NS	1.67
Slide 13	1.57	1.69	1.81	NS	1.70	1.64	1.72	NS	NS	1.70
x	1.55	1.67	1.74	1.74	1.73	1.71	1.67	1.62	1.59	1.61
s^2	0.02	0.003	0.002	0.002	0.00	0.01	0.001	0.01	0.00	0.00
s	0.15	0.05	0.05	0.05	0.02	0.08	0.03	0.03	0.01	0.06

[1]Ratios of 1.7 are considered free of phaeophytin and a ratio of 1.0 indicates phaeophytin in the absence of chlorophyll

* Autotrophic Index was calculated from the means of five values ash-free weight (mg/m^2) and five values chlorophyll a (mg/m^2) from each station

** NS = No Sample - Slide Lost

(Table 91). Station B1 showed a very high value of 1351.36 for the autotrophic index because the stream was intermittent and the sampler was buried in mud at times. Values decreased between stations B2, B3 and B4 with a small increase occurring at station B5. These four stations, B2, B3, B4 and B5 remained under the 100 level showing that the periphyton community was comprised of algal, i.e., autotrophic, biomass. From station B6, which had a high value for the autotrophic index, a decrease occurred through stations B7 and B8.

The before acidification:after acidification ratios were high at both Spring Creek stations. Station S1 had a very high numerical value (741.48) for the autotrophic index. It then decreased sharply at station S2 to 158.94.

Discussion of Results

Species Occurrence -

Diatom dominance on artificial substrates (October) - As seen in the previous chemistry section there were important shifts in certain chemical parameters. Most important of these, as they relate to the biological communities, were nutrient, TNT, and chloride (and other salt) concentrations in the aqueous phase. The relative significance of these shifts, as they affect the biota, appear not to severely alter the stream periphyton community within the area studied.

During the October survey, diatom species diversity from artificial substrates decreased with distance downstream. The high species diversity found at station B1 related to its conditions as a reference station, i.e., there were no industrial waste effluents influencing this station on its upstream side. Low levels of nutrients, chloride and TNT were found in the water.

The important trend in Brush Creek was the low species diversity occurring at the stations which received industrial wastes, (i.e. B2, B3, B4, B5, B6). These stations had higher chloride, nutrient and TNT levels present in the waters.

Recovery appeared to occur at stations B7 and B8 where species diversity increased. Once again station B7 had a high diversity with high aqueous phase TNT and nutrient levels. Under these conditions diversity is expected to decrease or be somewhat lower. This phenomenon is probably due to the incomplete mixing of effluent wastes in the water as was observed during the May-June survey. That is, the samplers may not have received the full impact of the wastes.

An increase in species diversity occurred between station S1 and station S2 of Spring Creek. By this time the construction activity upstream was creating a greater siltation problem at station S1 causing species diversity to diminish.

The truncated normal curve, when applied to the species data at each station, reflected the trend of species diversity. Stations B1, and B8 of Brush Creek and stations S1 and S2 of Spring Creek showed the modes of the curve to be high, indicating diverse periphyton communities. The remaining stations of Brush Creek had the height of the modes much lower, suggesting lower diversity of periphyton populations, somewhat similar to that characteristic of streams receiving organic pollution[28].

Species dominance did not shift greatly between the stations of Brush Creek. One species, Surirella angusta Kuetz. var. angusta was dominant at the six stations that possessed lower species diversity (B2, B3, B4, B5, B6 and B7). This species often occurs in alkaline waters (alkaliphil), having optimum growth around pH 7.5, but can exist in waters with pH levels up to 9[44]. This species is also indifferent to chlorides[44]. The common occurrence of this species in Brush Creek correlates with its recorded tolerance regimes and the water chemistry in which it was found ; i.e., pH 8.20 - 9.35 and chloride concentration of 109 mg/l - 353 mg/l (Table 5 Chemistry section.)

The dominant species at station B1 was Surirella ovata Kuetz. var. ovata and at station B8 was Navicula pseudoatomus Lund. var. pseudoatomus. These two species have recorded tolerance regimes[44] very similar to Surirella angusta Kuetz. var. angusta. At both stations, however, chlorides and pH levels were much lower and in part caused the shift in species dominance in Brush Creek.

Pinkham and Pearson coefficient of association grouped the Brush Creek stations on the basis of species occurrence. The six stations which had Surirella angusta Kuetz. var. angusta as the high dominant, were grouped most similar while stations B1 and B8 were grouped separately due to their high mutual species similarity.

Proximal station pairs within the Brush Creek system were very similar. Station pairs B2-B3, B3-B4, B4-B5, B5-B6, were similar above the 60 percent level. These stations were all affected by industrial wastes, either indirectly or directly. This observation indicates that change is not occurring between adjacent stations due to the industrial wastes, however, other trends, i.e., species diversity and shifts in species dominance, do suggest that a short term effect is taking place.

Similarity between station pairs, B1-B2, B6-B7, and B7-B8 were low. Station B2 received industrial wastes from effluents I1, I2, I3, and I4 resulting in its dissimilarity (5 percent similarity) with station B1, the reference station for Brush Creek. The domestic sewage treatment plant effluent which emanated just above station B7 caused species complex at this station to be less similar to station B6 (35 percent) due to different effluent effects. Stations B7 and B8 were dissimilar (25 percent) because of the direct effect of the waste treatment plant discharge on the periphyton community of station B7.

It can be concluded from these observations that the industrial effluents under study did affect the periphyton microcommunity of Brush Creek stations which received the IAAP industrial wastes, however, this was only a short term effect. Recovery was apparently occurring at

station B8 because of its dissimilarity to all other Brush Creek stations, its high diversity, and its different species composition.

Dominant species at stations S1 and S2 of Spring Creek were *Achnanthes lanceolata* (Breb.) Grun. var. *lanceolata* and *Nitzschia amphibia* Grun. var. *amphibia*, respectively. Both species are alkaliphils, found most frequently in water with pH levels of 7 - 9 and are indifferent to chlorides[44]. These two stations had lower pH levels (7.8) and lower chloride levels (90.8 mg/l - 40.9 mg/l, respectively) than the Brush Creek stations. Other occurring species did not represent more than 12 percent of the population.

Species dominance on natural substrates (October) - The biota collected from natural substrates were heavily influenced by the sediment chemistry in addition to the aqueous phase chemistry, since they were in contact with these bottom sediments. Most important of the sediment chemical parameters are total solids, total volatile solids, COD, TNT, nutrients and metals.

It was shown that combined species diversity from natural substrates was very similar to the trend seen on artificial substrates. Diversity on natural substrates was high at station B1 (reference station) where nutrient and aqueous TNT levels were low. Diatom diversity decreased in value between stations B2 and B7. Slight increases did occur at stations B3 and B6, however they were still lower than at station B1. The increase in diversity at these two stations suggests that recovery is occurring in the periphyton community in these regions, because both stations are not directly below an industrial waste effluent. Aqueous phase TNT and TNT levels in the sediments were very high at these stations (B2 - B7) except stations B3 and B6 where diversity increased. An increase in combined diatom species diversity at station B8 indicates recovery was occurring.

The Spring Creek stations showed a reverse trend in diversity between natural substrates (decrease from S1 and S2) and artificial substrates.

Aqueous TNT was not detectable at either S1 or S2, however there was measurable TNT in the sediments at S2. This observed trend appears to be associated with siltation and concentration of TNT in the sediments.

Diatom species diversity for samples collected from the sediment only showed an adverse effect associated with the TNT found in the sediments. The diversity values for stations B1 and B8 (reference and recovery station, respectively) were over 2.8, indicating that each microhabitat was very diverse. The remaining Brush Creek stations had lower species diversity values ranging from 0.65 to 1.79. Station B3 which exhibited low aqueous and sediment TNT levels, showed a slightly higher diversity of 2.2. It can be concluded that the sediments or sediment surfaces of Brush Creek supported different diatom associations during October than during May-June. This change in species association and diversity during the fall survey was also associated with higher measured levels of sediment TNT. These species variations may inpart be seasonal, however the association with TNT, although not conclusive, cannot be overlooked.

Species occurrence and dominance on natural substrates were similar to that occurring on the artificial substrates. The only variation in species dominance between artificial and natural substrates occurred at stations B1 and B8 of Brush Creek and stations S1 and S2 of Spring Creek. Station B1 and S2 both had _Surirella ovalis_ Breb. var. _ovalis_ as the dominant diatom species on natural substrates. This species is alkaliphilous, occurring in a pH range of 6.5 to 8.5 and indifferent to chlorides. As mentioned in the previous discussion section on species occurrence on artificial substrates, chloride levels and pH at these stations were relatively low compared to other stations. The dominant species on natural substrates at station B8 was _Surirella angusta_ Kuetz. var. _angusta_. This species' autecology was discussed in the previous discussion section on artificial substrates. _Nitzschia amphibia_ was dominant at station S1. This species autecology is also discussed in the previous discussion section on artificial substrates. At all four of these stations, pH levels, TNT (aqueous and sediment) levels and nutrient levels were lower than the other stations, probably allowing for the

species dominance to differ between natural and artificial substrates at these four stations. In contrast, the remaining seven stations had their dominant species the same for both substrate types.

The application of the Pinkham and Pearson coefficient of similarity showed all of the proximal stations of Brush Creek to be similar above 55 percent. However, stations B1 and B8 were less similar to stations B2 and B7, respectively, indicating that there was an effect upon the periphyton community within the stream at the stations where industrial effluents enter. This trend is very similar to that seen on the artificial substrates. It can be concluded from these observations that an affect on the periphyton communities occurred in Brush Creek due to the industrial effluents. However, it was shown that these affects were short termed and there was recovery occurring within the study areas.

Ash-Free Dry Weight -

The trend of ash-free dry weight in Brush Creek was similar to the species diversity trend on artificial substrates (refer to Biology results). The trend appeared to correspond to TNT concentrations found in the sediments and water. Increases and decreases that occurred between the stations were significant when the analysis of variance test was applied (Table 93). The change in ash-free dry weight between stations S1 and S2 of Spring Creek also followed TNT levels in the sediments and is significant (Table 93).

Chlorophyll -

Periphyton trends derived from chlorophyll *a* data showed a pattern very different from ash-free dry weight and species diversity. Changes that occurred between stations were of a larger magnitude than the changes in ash-free dry weight. These changes were shown to be significant by the analysis of variance (Table 94).

Table 93. ANALYSIS OF VARIANCE FOR ASH-FREE DRY WEIGHT. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. OCTOBER, 1975.

a. Brush Creek

Source	df	SS	MS	F
Total	35	205701.90		
Treat (between)	7	132551.36	18935.91	7.25*
Error (within)	28	73150.54	2612.52	

F (.95) = 2.35 *significant difference

b. Spring Creek

Source	df	SS	MS	F
Total	7	41999.26		
Treat (between)	2	36324.70	18162.35	16.00*
Error (within)	5	5674.56	1134.91	

F (.95) = 6.61 *significant difference

Table 94. ANALYSIS OF VARIANCE FOR CHLOROPHYLL a IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. OCTOBER, 1975.

a. Brush Creek

Source	df	SS	MS	F
Total	36	40.21		
Treat (between)	7	30.29	4.33	12.65*
Error (within)	29	9.94	0.34	

F (.95) = 2.35 *significant difference

b. Spring Creek

Source	df	SS	MS	F
Total	7	2.72		
Treat (between)	1	1.87	1.87	13.28*
Error (within)	6	0.85	0.14	

F (.95) = 5.99 *significant difference

Note: based on $mg/m^2/day$

Autotrophic Index -
The autotrophic index was also used to compare the periphyton associations in the two stream systems under study. This index was calculated from data obtained from the artificial substrates. Using the value of 100 described by Weber[36,29] as the level of significance between autotrophic and heterotrophic, most stations of Brush Creek showed indications of an autotrophic community, while the two Spring Creek stations were heterotrophic.

The degree of chlorophyll a variations were much greater than that seen in ash-free dry weight, thus causing the autotrophic index values to fall below the value of 100. At stations B1 and B6, chlorophyll concentrations were very low,while ash-free dry weight levels were high. This indicates that the population is composed of some heterotrophic organisms i.e., fungi, bacteria, and protozoa, or that organic detrital material is present, therefore resulting in a high value of the autotrophic index at these two stations.

Total volatile solids, total solids, and chemical oxygen demand did not fluctuate greatly between stations indicating that the presence of organic detrital material was probably not significant at any of the stations. This indicates that if non-viable organic material affected the periphyton mass measurement, it was somewhat equal at all stations therefore being insignificant. TNT in the water and sediments did seem to be an inhibitory factor to the organic fraction (ash-free dry weight) of the periphyton. TNT levels were not high at stations B1 and B6 which may have allowed the heterotrophic population to prosper thus increasing the ash-free dry weight causing the autotrophic index to be high (above 100). At those stations having higher levels of TNT there was a corresponding decrease in ash-free dry weight, disproportionate to changes in measured chlorophyll a levels. If the periphyton mass was 100 percent viable, or equally viable at all stations, this decrease in ash-free dry weight suggest the loss or inhibition of heterotrophic species. TNT and associated munitions wastes may be somewhat inhibitory to the heterotrophic fraction of periphyton microcommunities.

Station S1 and S2 showed values over 100 for the autotrophic index. Siltation problems and proportionately higher ash-free dry weight values compared to chlorophyll a values indicated the composition of the community in Spring Creek was not autotrophic.

Observed trends during the October sampling period indicated that the periphyton communities were affected by the industrial waste effluents, however recovery was occurring rapidly within the study are (station B8). This was the same trend as observed during the Spring.

The conclusions which can be drawn from these two surveys are:

1) Species diversity trends from both substrate types indicated minor shifts between stations, however any effect appears to be of only a short term duration. Recovery of the periphyton community was observed at different locations in the stream during both surveys, but it was always seen at station B8 in relation to station B1. This was also observed from the survey in 1974[1].
2) Observed fluctuations in the diversity of diatoms appeared to correspond with industrial outfalls.
3) The periphyton community occurring on the sediments appeared to be affected more(i.e., diversity) in the fall than in the spring, probably as a result of higher sediment TNT levels.
4) Species dominance and occurrence was very different during both surveys indicating seasonal changes. However, differences were not great between substrates.
5) Ash-free dry weight, chlorophyll a and autotrophic index trends were different between surveys. A heterotrophic population was more characteristic of May-June, while in October the population was more autotrophic.

6) Possible affects on the heterotrophic species, in terms of ash-free dry weight, were observed in Brush Creek during the fall survey only. There is an indication that some inhibitory factor(s) (i.e., TNT) is causing this trend. This also occurred in 1974 [1].

BENTHIC MACROINVERTEBRATES

Analytical Procedures

Preserved/stained samples were returned to the laboratory where they were again screened and washed in a fine mesh sieve (No. 40, U.S. Standard sieve). These samples were then picked and sorted in white enamel trays. A binocular dissecting microscope was used to identify all specimens and to sort specimens of the family Chironomidae into generic groups and subgroups. Head capsule slide mounts of the Chironomidae were made and specimens were identified to the generic level using a compound microscope 100 X and 400 X magnification.

Identifications were in accordance with the taxonomic keys listed in Appendix XV. Samples collected from the natural substrates and artificial substrates were processed and analyzed in a similar manner. All samples had been collected using quantitative techniques and data is expressed as numbers of individuals per square meter. The following conversion factors were applied to the species enumeration data:

Hester-Dendy multiplate sampler - 9.8
Petite ponar collections - 43.05
Surber square foot collections - 10.76

A species list detailing distribution was prepared and is included as Appendices XVI-XIX. Data was expressed as number of individuals per square meter.

Species diversity and evenness were determined for all replicate samples and plotted against station location. Mean species diversity and standard deviation of the replicate samples was calculated for trend analysis. Coefficient of similarity was used to compare replicate natural and replicate artificial substrate samples. Species data from replicate samples at each station were combined and compared to all other stations using the coefficient of similarity. Comparisons were also drawn between species occurrence from natural substrates and from artificial substrates at each station.

For the comparison of replicate and station similarity of benthic macroinvertebrate species data from artificial substrates, formula "B" of the Pinkham and Pearson Coefficient of Association was utilized. Mutual absence of species, i.e., 0/0 matches were scored as one[34,35]. This formula is used for samples collected from the same technique and when there are differences in density values between samples.

Species data taken from natural substrates were compared using the "B" formula and 0/0 matches scored as one. This formula is used when sampling methods between samples are not the same[34,35].

Results

Species Occurrence on Artificial Substrates (May-June) -

The trend of benthic macroinvertebrate species diversity on artificial substrates (Hester-Dendy plates) for Brush and Spring Creeks showed an irregular pattern. Replication of the five samples collected at each station was sometimes variable. Table 95 and 96 and Figure 64 show the values of species diversity and evenness calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. Of the five replicates, usually one and sometimes two were different from the remaining replicates at each station. This is indicated by some values occurring outside the limits of the standard deviation. The degree of replication is further verified

Table 95 SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTREATES. HESTER-DENDY PLATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK, BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	*	0.93	1.59	1.71	1.22	2.11	1.23	1.71	0.34	1.91
2		0.45	0.79	1.59	1.78	2.43	2.07	1.56	1.88	2.15
3		0.67	1.02	1.80	1.08	1.95	1.93	2.13	0.48	1.80
4		0.48	1.13	1.65	1.65	NS**	NS	2.35	0.43	1.80
5		0.61	0.98	1.59	2.20	NS	NS	1.68	0.35	2.02
x		0.63	1.10	1.67	1.59	2.16	1.74	1.89	0.70	1.94
s^2		0.037	0.089	0.008	0.202	0.060	0.203	0.114	0.441	0.023
s		0.192	0.299	0.089	0.450	0.244	0.450	0.337	0.664	0.150

* no collection due to extremely shallow water

** NS = no sample - sampler lost

Table 96. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTRATES. HESTER-DENDY PLATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK, BURLINGTON, IOWA. MAY - JUNE 1975

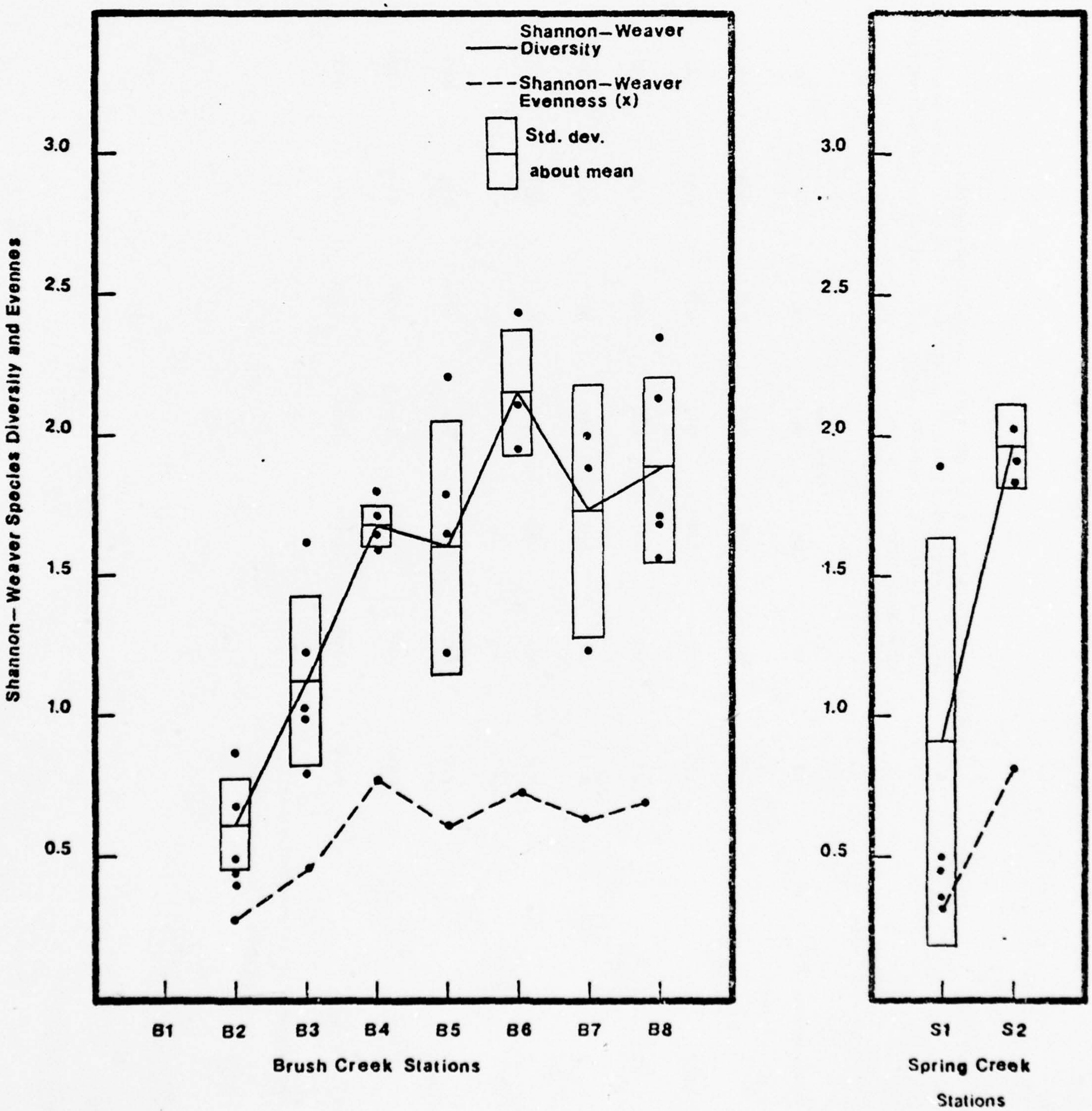
	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	*	0.41	0.66	0.78	0.49	0.74	0.44	0.59	0.19	0.75
2		0.22	0.41	0.88	0.72	0.78	0.70	0.57	0.78	0.80
3		0.27	0.41	0.73	0.42	0.68	0.75	0.86	0.27	0.72
4		0.19	0.45	0.64	0.64	NS**	NS	0.80	0.18	0.82
5		0.24	0.36	0.82	0.75	NS	NS	0.62	0.21	0.84
x		0.27	0.46	0.77	0.60	0.73	0.63	0.69	0.33	0.79
s^2		0.007	0.014	0.008	0.021	0.003	0.028	0.018	0.066	0.002
s		0.086	0.117	0.091	0.144	0.050	0.166	0.132	0.256	0.050

* no collection due to extremely shallow water.

** NS = no sample - sampler lost

FIGURE 64. Shannon-Weaver Species Diversity and Evenness of Benthic Macroinvertebrates Collected from Five Replicate Artificial Substrates—Hester Dendy Plates. Iowa Army Ammunition Plant, Brush and Spring Creek. Burlington, Iowa.

May-June 1975



through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) At station B1, the Hester-Dendy plates were not analyzed for species occurrence. This resulted from flow at this station being intermittent and the plates were never completely submerged; therefore station B1 is not considered.
2) At station B2 there were four replicate samples which were similar above the 50 percent level (Figure 65), while the fifth replicate was similar to the other four below 40 percent. The mean species diversity at this station remains at 0.63 (Table 95) even when the fifth (i.e. most different) replicate is ignored.
3) Replication of samples at station B3 was variable. No two replicates were similar above 60 percent (Figure 66), however the five replicates together were similar at the 40 percent level. Mean species diversity calculated for all five replicates at this station was 1.10 and did not change even when the two most different replicates were omitted.
4) The five replicate samples at station B4 were similar at the 35 percent level (Figure 67). Two replicates were similar at 65 percent while two other replicates were similar at 45 percent. The mean species diversity (1.67) is representative of this station because it remains constant when the most different of the five samples is ignored.
5) At station B5 the five replicates collected were similar above the 40 percent level (Figure 68). When ignoring the most different replicate the mean species diversity decreases from 1.59 to 1.43.
6) The three replicate samples at station B6 (only three replicates due to the fourth and fifth being lost) were similar at the 30 percent level (Figure 69). Two of the three replicates were similar at 40 percent. Mean species diversity (2.16) did change to 2.03 when the least similar replicate was eliminated.

Figure 65.

STATION B2-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

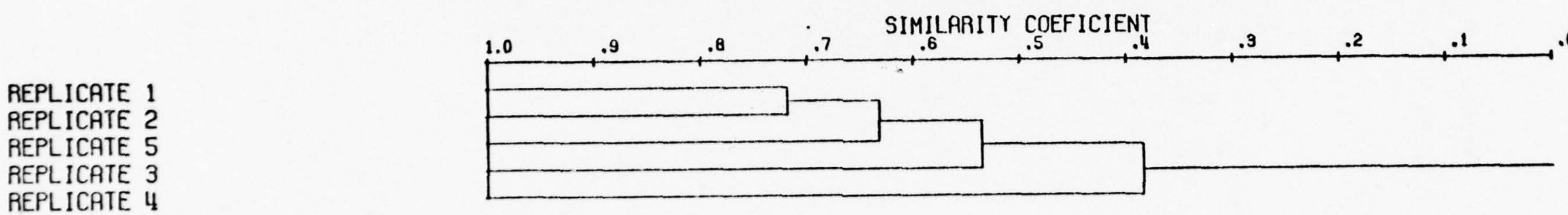


Figure 66.
STATION B3-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

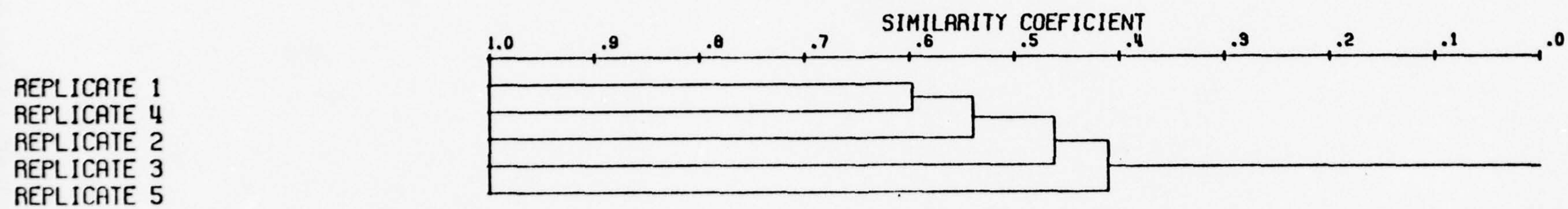


Figure 67.

STATION B4-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

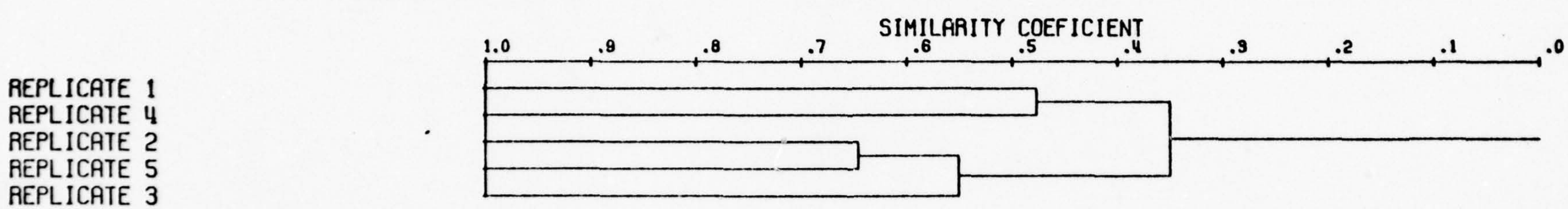


Figure 68.

STATION B5-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

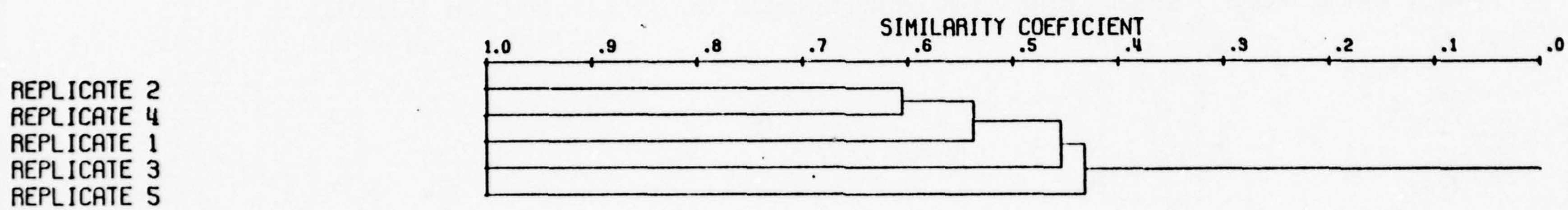


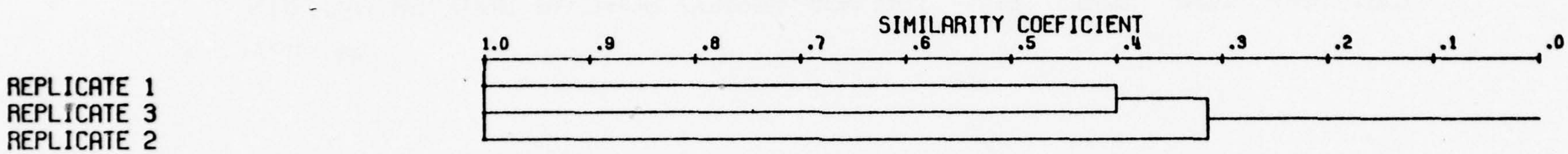
Figure 69.

STATION B6-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



7) At station B7 again only three samples were retrieved, with two replicates being similar at the 40 percent level (Figure 70). All replicates together were similar at 25 percent. The mean species diversity at this station decreased from 1.74 to 1.53 when eliminating the least similar replicate.

8) Replication of benthic macroinvertebrate species associations at station B8 (Figure 71) was similar above the 45 percent level. The differences between the replicates did not change the mean species diversity (1.89).

9) Station S1 of Spring Creek showed three replicates out of the five samples retrieved to be similar (65 percent) (Figure 72). The two remaining samples were only similar at 45 and 38 percent. Ignoring the two most different replicates, the mean species diversity decreased from 0.70 to 0.39 which is probably more representative of the benthic macroinvertebrate community at this station.

10) At station S2 the benthic macroinvertebrate species distribution of the five replicates was similar above the 40 percent level (Figure 73) with two replicates being similar above 50 percent and two others being similar above 55 percent. Calculating the mean species diversity for the four replicates as mentioned above, the value remains near 1.94, as when calculated using all five replicate samples.

The application of species diversity and coefficient of similarity to the replicate samples at every station, particularly the coefficient of similarity, indicates whether or not a sufficient sample has been taken to adequately describe the existing community. It was shown that most often one or two of the five replicate samples was quite different from the remaining samples and the presence or absence of its species data had little effect on the estimation of benthic macroinvertebrate community structure, i.e., species diversity. Thus, the inclusion of all replicate samples on a combined basis at each station provided a broader species complex from which station-to-station comparisons

Figure 70.

STATION B7-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

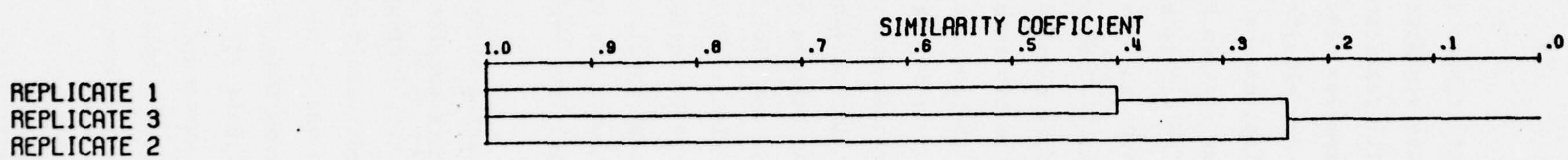


Figure 71.
STATION B8-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

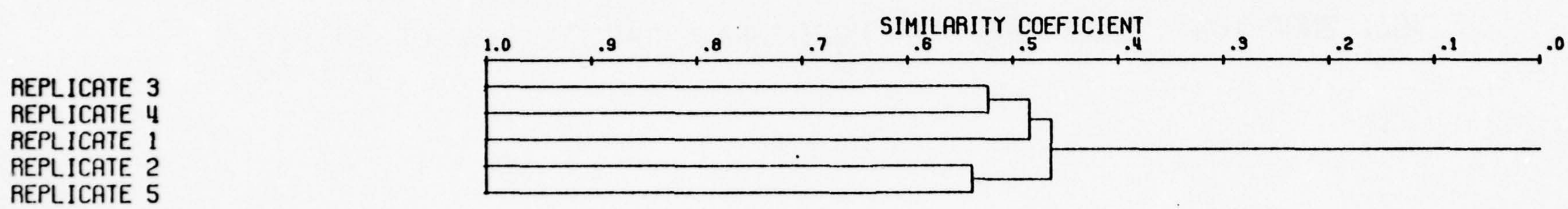


Figure 72.
STATION S1-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

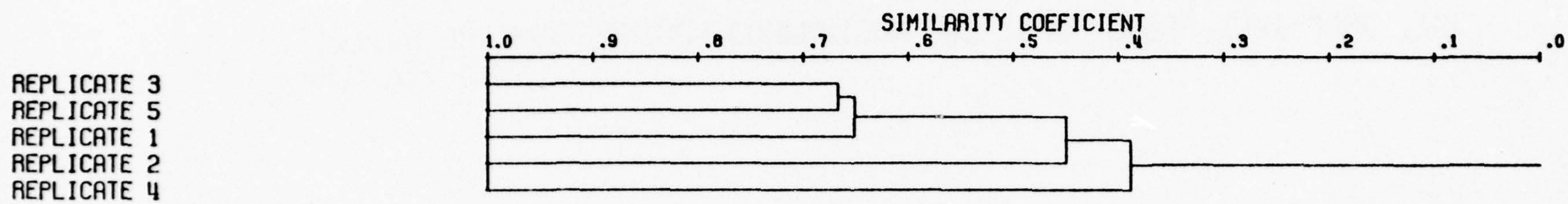
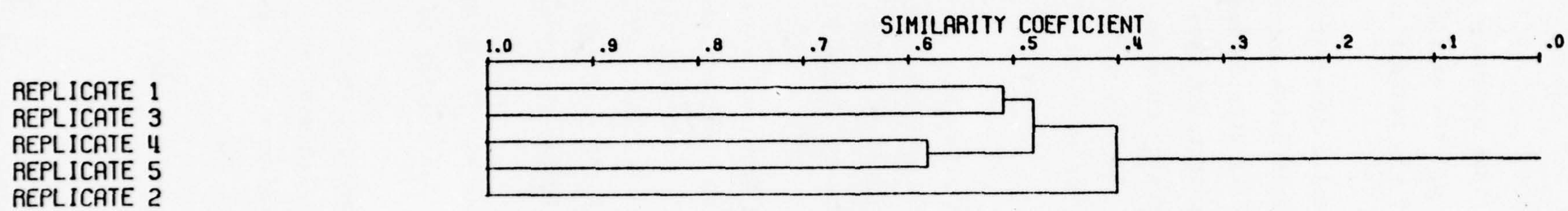


Figure 73.
STATION S2-IAAP BENTHOS COMPARISON ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



were made. This approach included the occurrence of many rare and uncommon species but did not significantly alter the calculated mean species diversity at the respective stations.

The mean species diversity of benthic macroinvertebrates collected from artificial substrates increased sharply from station B2 to station B4. Station B5 diversity decreased only slightly from that of station B4, with a sharp increase then occurring at station B6. (Table 95;Figure 64). Species diversity then decreased at station B7 with a slight increase at station B8. Species evenness (Table 96; Figure 64) showed a parallel trend with species diversity, but decreases and increases were more gradual.

Species diversity differed considerably between the two Spring Creek stations.A large increase in diversity occured between station S1 (0.70) and station S2 (1.94) (Table 95; Figure 64). Species evenness paralleled species diversity (Table 96; Figure 64).

Species data from replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in these stations being grouped similar: B3 and B7 (59 percent); B4,S1 and S2 (62 percent); and B6 and B8 (54 percent) (Table 97; Figure 74). Stations B5 and B2 were least similar to any of these station groups.

Station groups B3, B7 and B4, S1, S2 were similar at 58 percent. Station B5 by itself was similar to this group at 50 percent.

Stations B6 and B8, (similar at 54 percent) were similar to the previous six stations mentioned at a level above 45 percent. Station B2 was the least similar to all the stations at about 42 percent.

Table 97. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATIONS BASED ON COMBINED ARTIFICIAL SUBSTRATE (HESTER-DENDY PLATES) REPLICATES AT EACH STATION, IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. MAY-JUNE, 1975.

	Brush Creek							Spring Creek	
Stations	B2	B3	B4	B5	B6	B7	B8	S1	S2
B2	1.000								
B3	0.535	1.000							
B4	0.490	0.595	1.000						
B5	0.445	0.476	0.566	1.000					
B6	0.425	0.478	0.533	0.466	1.000				
B7	0.453	0.587	0.575	0.540	0.534	1.000			
B8	0.452	0.479	0.523	0.430	0.541	0.487	1.000		
S1	0.458	0.631	0.667	0.459	0.481	0.567	0.500	1.000	
S2	0.490	0.541	0.641	0.502	0.536	0.568	0.515	0.619	1.000

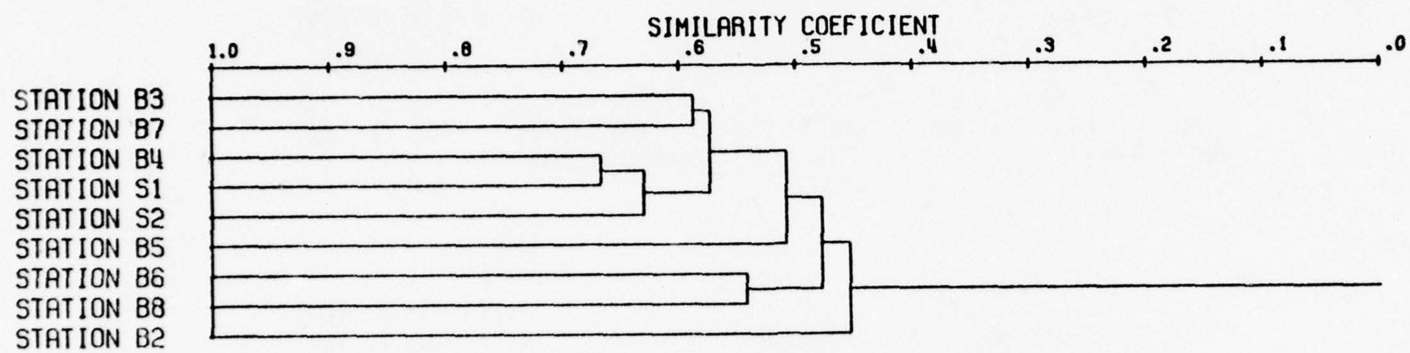
Figure 74.

IAAP BENTHOS-STATION COMPARISON-COMBINED REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



Percent dominance of the benthic macroinvertebrate species occurring on artificial substrates was calculated from the species list in Appendix XVI . During May-June 1975, there was one taxon at station B2 that comprised 87 percent of the benthic macroinvertebrate community. This taxon was the chironomid, Cricotopus sp. The remaining 13 percent of the population was comprised of 29 taxa.

At station B3, Cricotopus sp. remained dominant but comprised only 56 percent of the population. The co-dominant was the isopod, Asellus sp. (26 percent). Thus, these two taxa together comprised 82 percent of the total macroinvertebrate dominance at this station.

Three taxa present at station B4 comprised 71 percent of the total community structure. Asellus sp. increased two percent from station B3 to 28 percent and became the dominant. Cricotopus sp. occurred at 24 percent with the mayfly Heptagenia diabasia establishing itself at 19 percent.

Cricotopus sp. (48 percent) was the most abundatn taxon of three which comprised 69 percent of the benthic macroinvertebrate community at station B5. The other two taxa, also chironomids, Pentaneura sp.(11 percent) and Polypedilum sp. (10 percent).

At station B6, three taxa comprised 61 percent of the population with Cricotopus sp. decreasing in frequency to a low of one percent. Species occurring in decreasing order were Agraylea multipunctata (31 percent), Asellus sp. (20 percent) and Physa integra (10 percent).

Station B7 also had three species together comprising 71 percent of the total macroinvertebrate population. Agraylea multipunctata remained dominant increasing to 44 percent. Cricotopus sp. and Physa integra were present at 18 percent and nine percent, respectively.

Agraylea multipunctatadecreased from 44 percent at station B7 to 36 percent at station B8. Polypedilum sp. and Pentaneura sp. were both present at 19 percent. Therefore, three taxa comprised 82 precent of the macroinvertebrate community at station B8.

Spring Creek species dominance was different from the Brush Creek stations. Station S1 had one taxon, Asellus sp., which comprised 90 percent of the benthic macroinvertebrate association.

At station S2, three benthic macroinvertebrate taxa comprised 61 percent of the total population. Thirty percent was represented by Cladotanytarsus sp., a chironomid. The remaining two taxa were Asellus sp. (16 percent) and Dicrotendipes sp. (15 percent).

Differences in the benthic macroinvertebrate community structure and similarity which occurred between the sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare macroinvertebrates. To summarize Appendix XVI , stations B2 and B3 both had 30 taxa, with station B4 having only 24 taxa. Thirty-three and 34 taxa were found at stations B5 and B6, respectively. Station B7 had 26 taxa and station B8 had 37 taxa. Stations S1 and S2 of Spring Creek had 23 and 22 taxa, respectively.

Species Occurrence on Natural Substrates (May-June) - Samples collected from natural substrates included samples taken with a petite ponar and surber square foot sampler. Species data from these two sample types were analyzed for diversity, evenness, species association and species dominance.

Ponar samples - Two replicate ponar samples were taken at each sampling station, except stations B1 and B2 of Brush Creek where five replicates were taken. More than two replicates were taken at these two stations because a well-developed riffle was not present within the sampling area for collection with the surber square foot sampler.

Mean species diversity of the two or five replicate samples at each station showed an irregular pattern. Table 98 and 99 and Figure 75 show the values of species diversity and evenness calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. Replication of the two or five samples

Table 98 SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES
COLLECTED FROM NATURAL SUBSTRATE- PONAR. IOWA ARMY AMMUNITION PLANT.
BRUSH AND SPRING CREEK, BURLINGTON, IOWA. MAY - JUNE 1975

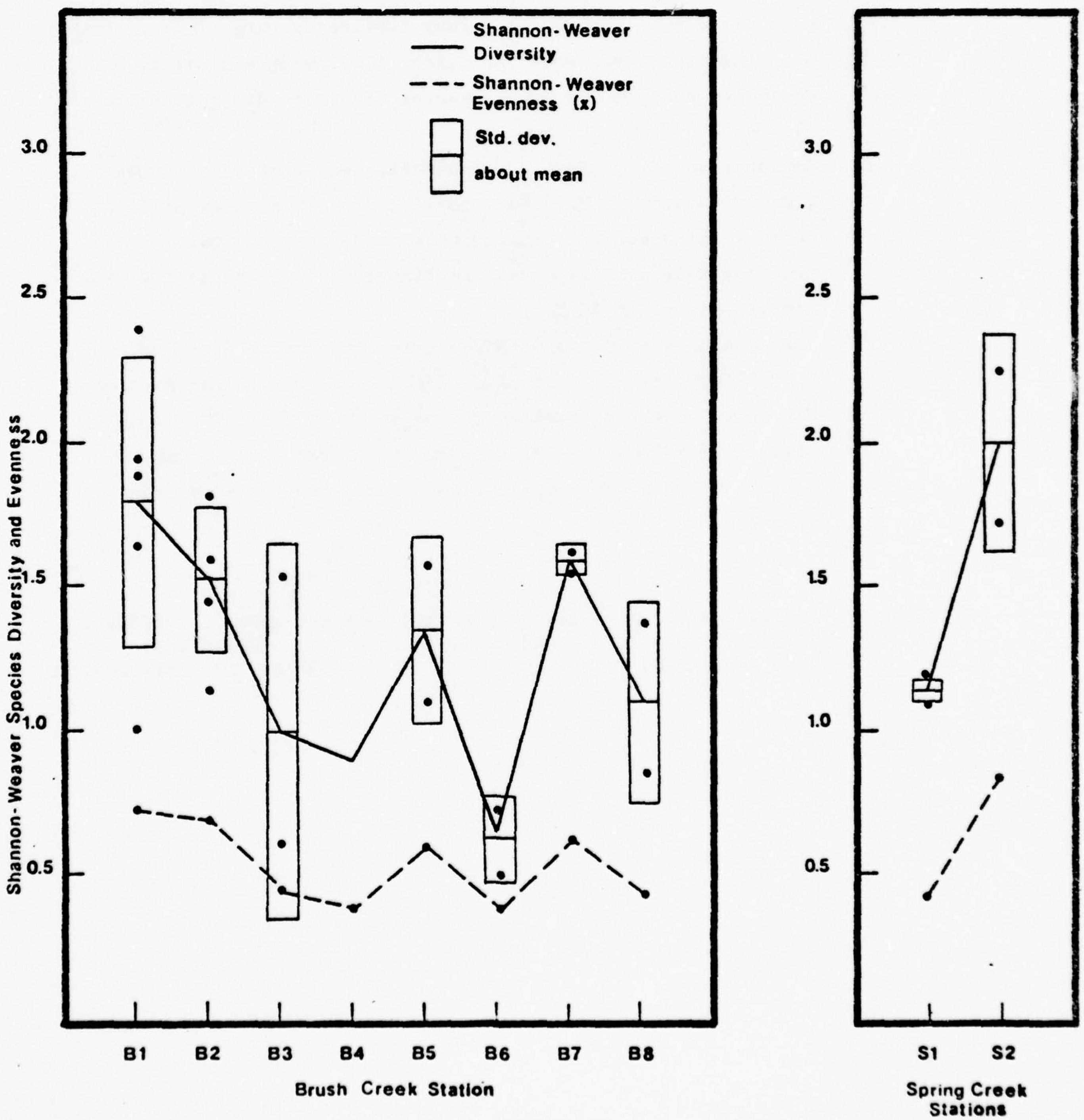
	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	1.89	1.14	0.61	0.90	1.57	0.73	1.62	1.37	1.10	2.26
2	1.66	1.60	1.53	0.91	1.11	0.51	1.56	0.85	1.17	1.72
3	1.96	1.82								
4	1.06	1.45								
5	2.41	1.60								
x	1.79	1.52	1.07	0.90	1.34	0.62	1.59	1.11	1.14	1.99
s^2	0.242	0.063	0.423	0.000	0.106	0.024	0.002	0.135	0.002	0.146
s	0.492	0.251	0.650	0.007	0.325	0.156	0.042	0.368	0.050	0.382

Table 99 SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES
COLLECTED FROM NATURAL SUBSTRATE - PONAR, IOWA ARMY AMMUNITION PLANT.
BRUSH AND SPRING CREEK. BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Sample replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	0.76	0.52	0.26	0.37	0.71	0.53	0.74	0.55	0.43	0.94
2	0.72	0.77	0.62	0.38	0.51	0.21	0.52	0.31	0.43	0.75
3	0.85	0.79								
4	0.46	0.58								
5	0.87	0.73								
x	0.73	0.68	0.44	0.38	0.61	0.37	0.63	0.43	0.43	0.84
s^2	0.027	0.014	0.065	0.000	0.020	0.051	0.024	0.029	0.000	0.018
s	0.164	0.121	0.254	0.007	0.141	0.226	0.156	0.170	0.000	0.134

FIGURE 75. Shannon-Weaver Species Diversity and Evenness of Benthic Macroinvertebrates Collected from Natural Substrate—Ponar. Iowa Army Ammunnition Plant, Brush and Spring Creek, Burlington Iowa.

May–June 1975



for each station was sometimes variable. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) Of the five ponar replicates collected at station B1, one was most different (Figure 76). Four replicates were similar above 50 percent, however when the fifth (i.e., most different) replicate was ignored, mean species diversity did not change (1.79).
2) Replication of the five samples collected at station B2 was similar to station B1. Four replicates were similar at 50 percent while one was similar only at 39 percent (Figure 77). Ignoring this most different replicate did not change the mean species diversity (1.52).
3) The remaining stations of Brush Creek and Spring Creek each had collections of two replicate ponar samples. Mean species diversity at these stations can be found in Table 98 and similarity values for the two replicates can be found in Table 100. Note that replication of only two replicates is very low.

Table 100. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATION BASED ON TWO REPLICATE PONAR SAMPLES, IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. MAY-JUNE, 1975

Stations	Ponar Replicates
B1	
B2	
B3	0.198
B4	0.262
B5	0.314
B6	0.110
B7	0.115
B8	0.116
S1	0.093
S2	0.156

Figure 76.
STATION B1-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (MAY-JUNE '75
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

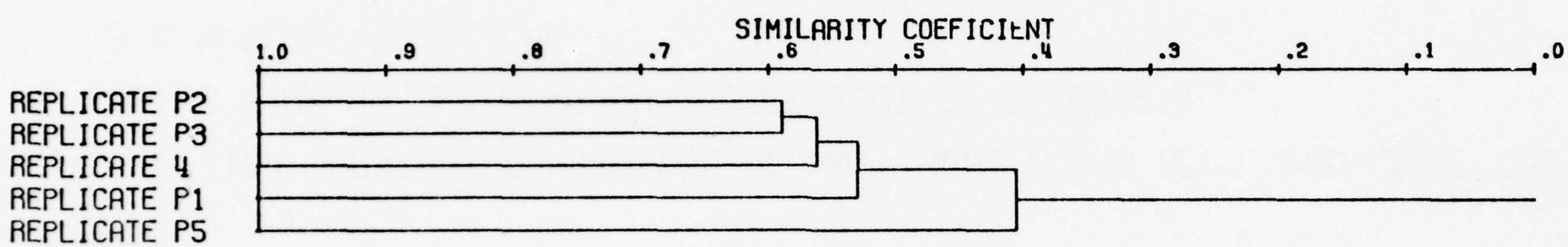
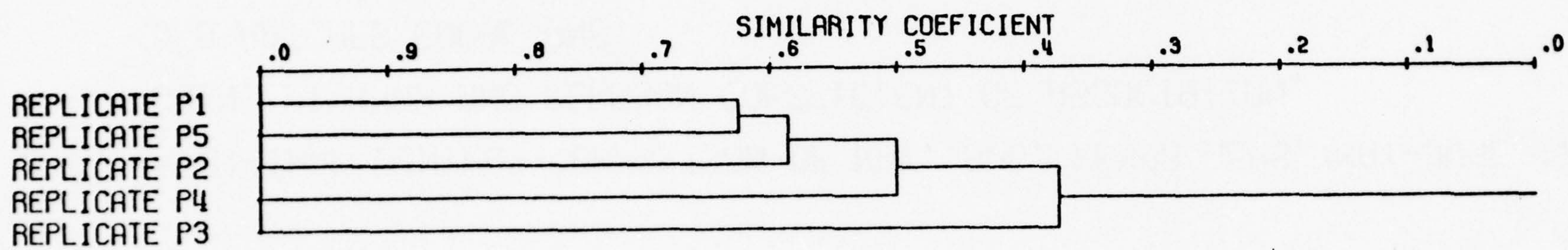


Figure 77.
STATION B2-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (MAY-JUNE '75

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



The application of species diversity and coefficient of similarity to the replicate samples at each station, particularly the coefficient of similarity, indicates whether or not a sufficient sample has been taken to adequately describe the existing community. This approach included the occurrence of many rare and uncommon species but did not alter the calculated mean species diversity at the representative stations.

Mean species diversity of benthic macroinvertebrates collected by ponar grabs sharply decreased from station B1 (1.79) to station B4 (0.90) (Table 98; Figure 75). An increase occurred at station B5 (1.35) and decreased to the lowest value of diversity (0.62) recorded for Brush Creek at station B6. Station B7 (1.59) showed a two-fold increase with station B8 dropping to a diversity of 1.11. Species evenness (Table 99; Figure 75) showed a parallel trend with species diversity.

Species diversity differed between the two Spring Creek stations. An increase of 0.85 occurred between station S1 (1.14) and station S2 (1.99). Species evenness paralleled species diversity.

Species data from ponar replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in seven stations (B5, B6, S2, B3, B4, B8 and B7) being grouped due to the relatively high species similarity between them. (Table101; Figure 78). Stations B2 of Brush Creek and S1 of Spring Creek were similar at 59 percent. These two groups of stations (B5, B6, S2, B3, B4, B8, B7 vs. B2, S1) were similar at 51 percent. Station B1 of Brush Creek was the least similar to all stations (40 percent).

Percent dominance of macroinvertebrate species occurrence was calculated from the species list in Appendix XVII.At station B1, three species comprised 70 percent of the macroinvertebrate community. The Tubificidae were dominant at 38 percent while the co-dominant was *Palpomyia tibialis* (19 percent). *Asellus* sp. also occurred at this station (13 percent).

Table 101. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATE (PONAR METHOD) REPLICATES AT EACH STATION. IOWA ARMY AMMUNITION PLANT BRUSH AND SPRING CREEKS, BURLINGTON, IOWA. MAY-JUNE, 1975

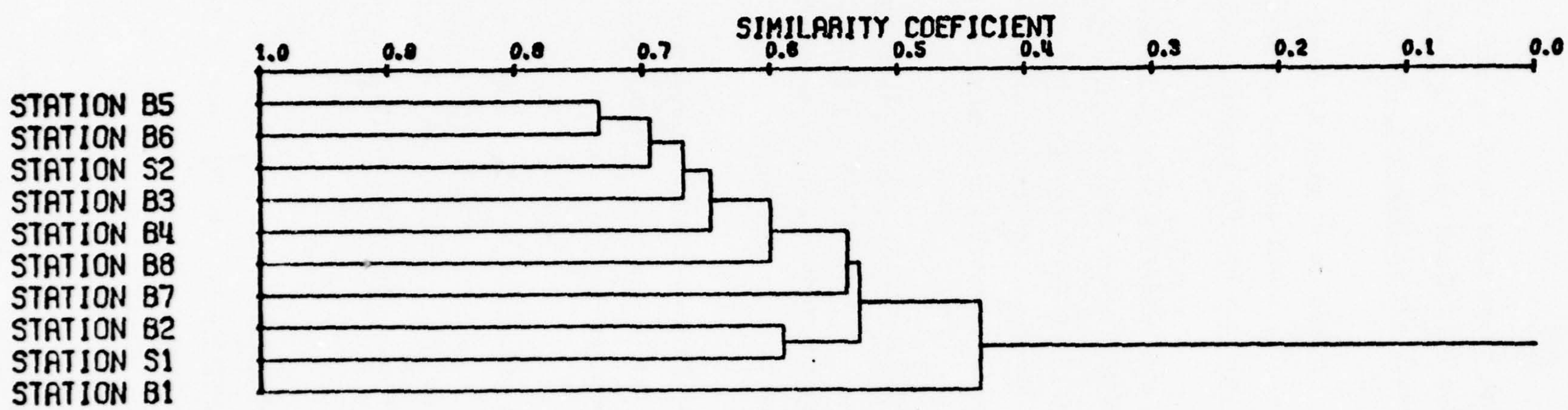
Stations	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
B1	1.000									
B2	0.446	1.000								
B3	0.515	0.609	1.000							
B4	0.474	0.574	0.659	1.000						
B5	0.529	0.613	0.694	0.630	1.000					
B6	0.597	0.610	0.671	0.643	0.734	1.000				
B7	0.362	0.498	0.540	0.565	0.594	0.602	1.000			
B8	0.401	0.459	0.556	0.614	0.556	0.679	0.511	1.000		
S1	0.485	0.590	0.614	0.581	0.639	0.640	0.556	0.488	1.000	
S2	0.470	0.550	0.654	0.631	0.708	0.681	0.604	0.611	0.602	1.000

Figure 78.
IAAP BENTHOS-STATION COMPARISON OF NAT. SUB.-PONAR REP. (MAY-JUNE 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION.

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



There were three taxa which comprised 76 percent of the benthic association at station B2. These were Cricotopus sp. (36 percent), Stictochironomus sp. (32 percent) and Palpomyia tibialis (8 percent).

Two taxa present at station B3 comprised 82 percent of the total population. They were also found dominant at station B2. Both species were chironomids, Stictochironomus sp. (76 percent) and Palpomyia tibialis (6 percent).

The same two taxa from station B3 were dominant at station B4. They both increased in percent occurrence. Strictochironomus sp. increased from 76 percent to 80 percent and Palpomyia tibialis, increased from six percent to eight percent. Together, these two species comprised 88 percent of the benthic macroinvertebrate community at station B4.

A new dominant taxon, Cryptochironomus sp. 2 (62 percent) appeared at Station B5. Two other taxa, Stictochironomus sp. (10 percent) and Cricotopus sp. (five percent) together comprised 15 percent of the benthos population at this station.

At station B6, one taxon comprised 88 percent of the benthic population. This was the chrionomid, Stictochironomus sp. The remaining 12 percent was composed of 11 other taxa.

Palpomyia tibialis (47 percent)became the new dominant species at station B7. Stictochironomus sp., Cricotopus sp. and Physa integra occurred at 18 percent, 10 percent and 12 percent, respectively. Together these four taxa comprised 87 percent of the total macroinvertebrate community.

Station B8 had two taxa comprising 85 percent of the population. Stictochironomus sp. was dominant at 64 percent with Polypedilum sp. being co-dominant (21 percent)

Spring Creek species dominance was somewhat different from Brush Creek. At station S1, Asellus sp. comprised 53 percent of the macroinvertebrate population. Stictochironomus sp. occurred at 22 percent. A total of 75 percent of the benthos community was comprised of these two taxa.

At station S2, 66 percent of the population was comprised of three taxa. Thirty-four percent was represented by Stictochironomus sp. as compared to 22 percent at station S1. Chironomus anthracinus was present at 20 percent and Tubificidae at 12 percent.

To summarize Appendix XVII, total number of taxa decreases moving downstream. The most upstream and down stream stations B1, B2, B7 and B8 averaged 25 taxa, however, the mid-stream stations only averaged 15 total taxa per station. Station S1 and station S2 had 22 and 16 representative taxa, respectively.

Surber square foot sampler - Three replicate surber samples were taken at each station except for stations B1 and B2 of Brush Creek (see introduction to ponar sampling).

Mean species diversity of the three replicate samples at each station showed little change between stations. Table 102 and 103 and Figure 79 give the values of species diversity and evenness calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. Replication of the three samples for each station was sometimes variable. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) At station B3 the benthic macroinvertebrate distribution of the three replicates was similar at 35 percent, with two replicates being similar above 40 percent (Figure 80). The mean species diversity (1.99) did not change when the most different replicate was ignored.

Table 102 SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM NATURAL SUBSTRATE - SURBER. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. MAY - JUNE 1975

	Brush Creek								Spring Creek	
Sample replicates	B1*	B2*	B3	B4	B5	B6	B7	B8	S1	S2
1			2.33	2.14	1.61	1.72	1.78	2.01	2.40	2.13
2			2.15	2.02	2.50	2.22	1.65	2.31	2.12	2.19
3			1.51	2.19	1.78	2.31	2.39	1.95	2.29	2.37
x			1.99	2.11	1.96	2.08	1.94	2.09	2.27	2.23
s^2			0.176	0.007	0.223	0.101	0.156	0.037	0.020	0.014
s			0.420	0.085	0.472	0.318	0.395	0.193	0.141	0.119

* Due to substrate limitations no surber square foot samples were collected.

Table 103 SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM NATURAL SUBSTRATE - SURBER. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. MAY - JUNE 1975.

	Brush Creek								Spring Creek	
Sample replicates	B1 *	B2 *	B3	B4	B5	B6	B7	B8	S1	S2
1			0.90	0.78	0.57	0.64	0.60	0.68	0.82	0.86
2			0.79	0.76	0.83	0.80	0.64	0.75	0.74	0.71
3			0.58	0.85	0.67	0.69	0.86	0.67	0.79	0.79
x			0.76	0.80	0.69	0.71	0.70	0.70	0.78	0.79
s^2			0.026	0.002	0.017	0.007	0.020	0.002	0.002	0.006
s			0.162	0.047	0.131	0.082	0.140	0.044	0.040	0.075

* Due to substrate limitations no surber square foot samples were collected.

FIGURE 79. Shannon-Weaver Species Diversity and Evennes of Benthic Macroinvertebrates Collected from Natural Substrate – Surber. Iowa Army Ammunition Plant. Brush and Spring Creek, Burlington Iowa.

May – June 1975

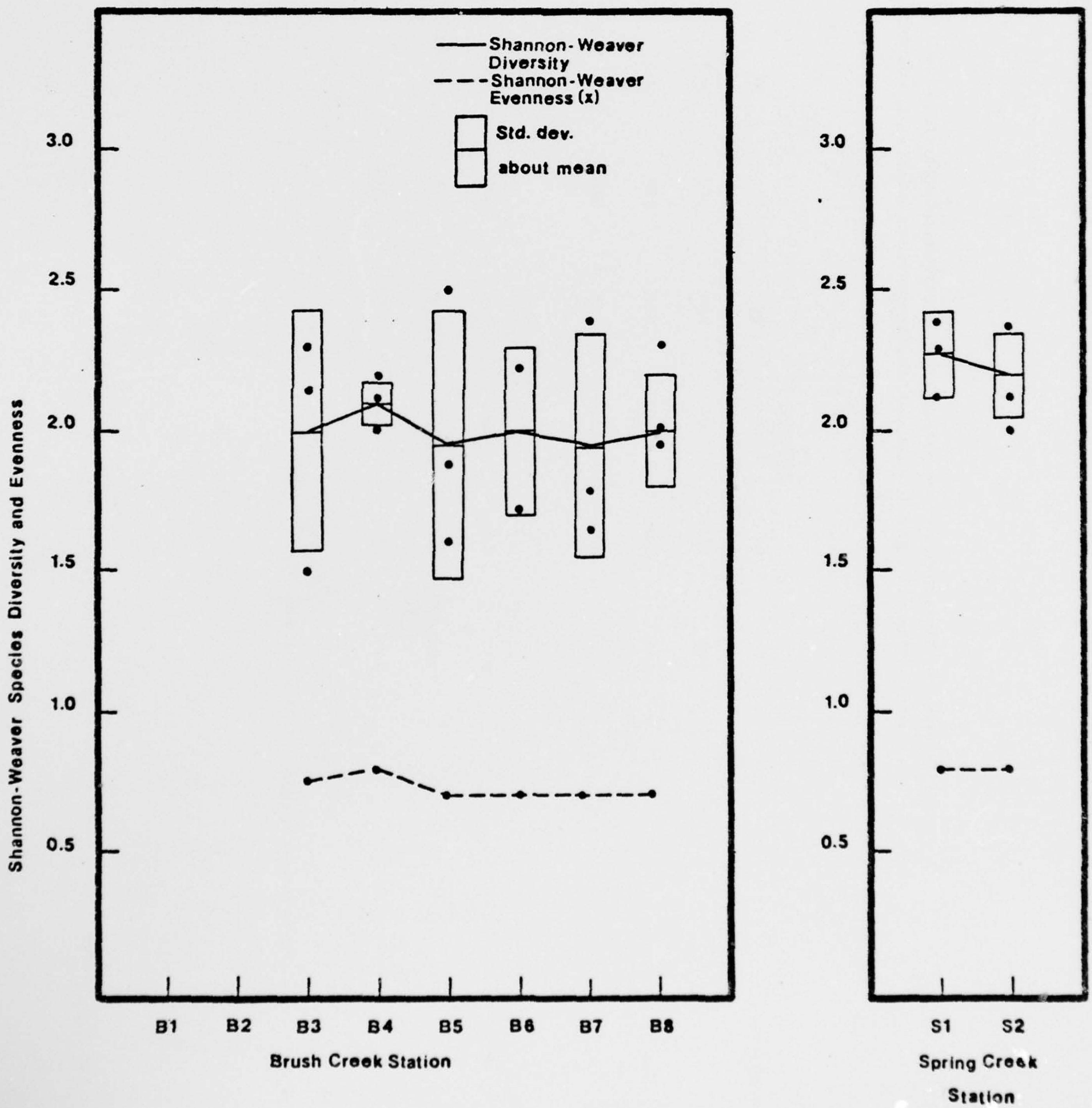


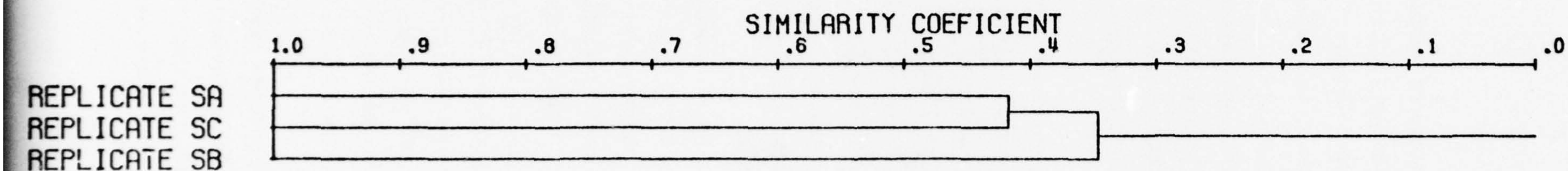
Figure 80.

STATION B3-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



2) Replication of samples at station B4 was higher. Two samples were similar at 55 percent while the third was similar above 40 percent (Figure 81). Even when the third replicate is not considered, mean species diversity (2.11)does not change significantly.

3) The three replicate surber samples at station B5 were similar at the 29 percent level (Figure 82). Two of these replicates were similar at 42 percent, however the elimination of the least similar sample does not change the mean species diversity (1.96).

4) At station B6 two replicates were similar at 55 percent while the third was only similar at 22 percent (Figure 83). Mean species diversity (2.08) did not change when ignoring the least similar replicate.

5) Station B7 showed a similarity above the 25 percent level for three replicate samples (Figure 84). Two of these were similar above 55 percent, however, mean species diversity did not change appreciably with elimination of the least similar replicate.

6) Replication of benthic macroinvertebrate associations at station B8 (Figure 85) was similar at 35 percent. Two replicates were similar above 45 percent. Ignoring the most different replicate, mean species diversity at this station decreased from 2.09 to 1.98, an insignificant change.

7) Station S1 of Spring Creek had its three replicates similar above 25 percent with two replicates similar above the 50 percent level (Figure 86). Mean species diversity (2.27) was not changed when the least similar replicate was ignored.

8) At station S2 the mean species diversity was 2.23. Replication of the three samples was similar above 25 percent (Figure 87).

The application of species diversity and coefficient of association to the replicate samples at every station, particularly the coefficient of similarity, indicates whether or not a sufficient sample has been taken to adequately describe the existing community. In most cases, one

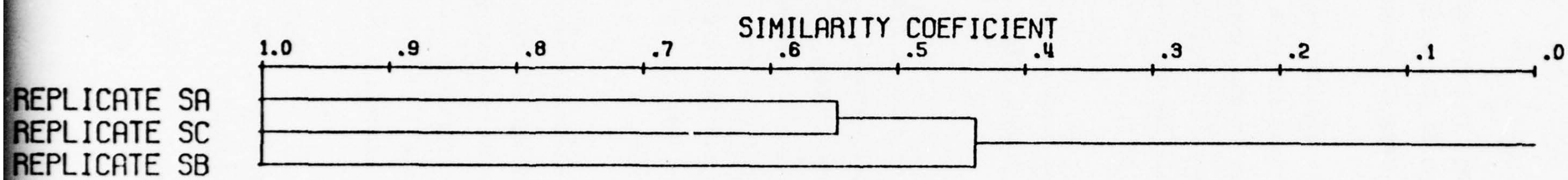
Figure 81.

STATION B4-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



a community composed proportionally of more algae than the previous stations. Stations B2 and B6 had the highest biomass of algae (Table 77) and likewise have the lowest non-algal biomass/ATP ratios.

As the value of the organic weight/ATP ratio and the non-algal biomass/ATP ratio approach each other it suggests a large percentage of the ash-free dry weight (organic weight) is living and proportionally more heterotrophic. Furthermore, if the AI is greater than 100, it reflects a viable heterotrophic association. This is seen at station B7 (Table 79).

Greater differences between these two ratios accompanied by low AI values suggests a viable algae association. This is seen at station B2.

The other extreme is seen at station B8. High ratios of organic weight and non-algal biomass to ATP, accompanied by a very high AI value, suggest a heterotrophic community of low activity. It is probable that a large fraction of the ash-free dry weight is non-viable. The conversion of data indicates that about 88 percent of the periphyton at this station is non-algal (Table 77). Of this non-algal, organic mass most is probably non-living detrital, or moribund cells of heterotrophs.

At station S2 the AI indicates slight heterotrophism. The ratios of ATP suggest very low activity but also indicate that there may be a large fraction of non-living organic material (Table 79). The organic weight may represent a large portion of algae, algal biomass was 47 percent (Table 77) , and the non-algal biomass may be non-living, which would increase the AI value.

ATP/Organic Weight and ATP/Chlorophyll *a* -

One last comparison was to look as the levels of ATP/mg ash-free dry weight and ATP/mg chlorophyll *a*. The level of ATP decreased between

Figure 83.

STATION B6-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

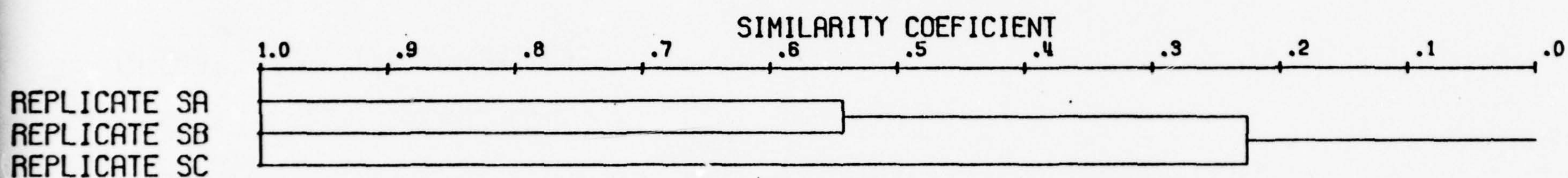


Figure 84.

STATION B7-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

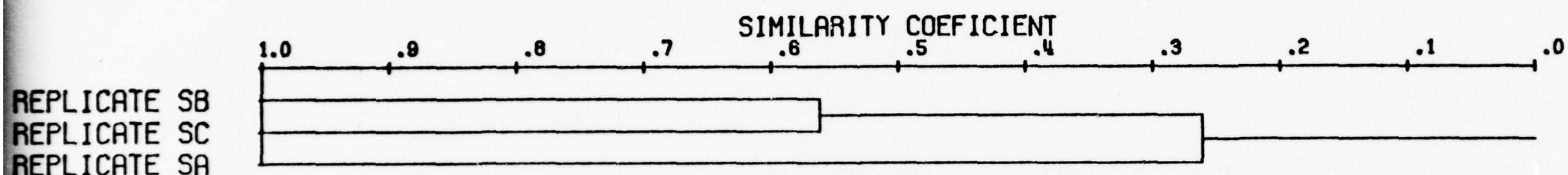


Figure 85.
STATION B8-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

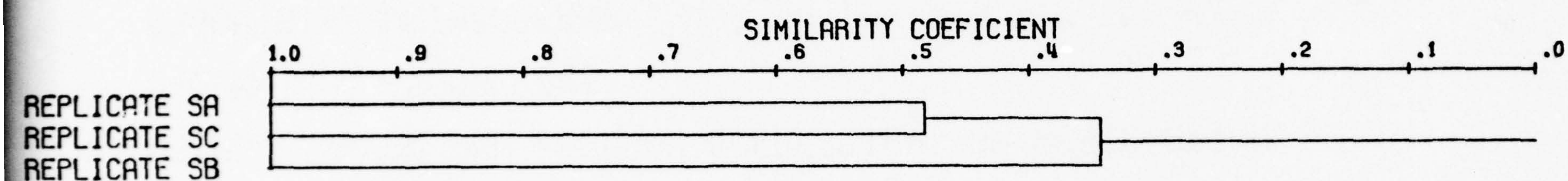


Figure 86

STATION S1-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

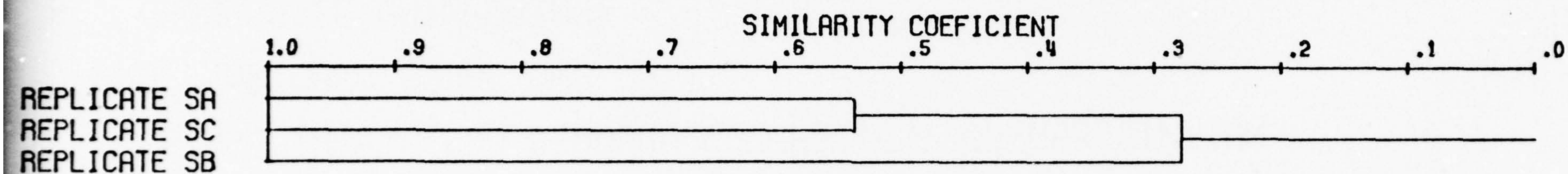
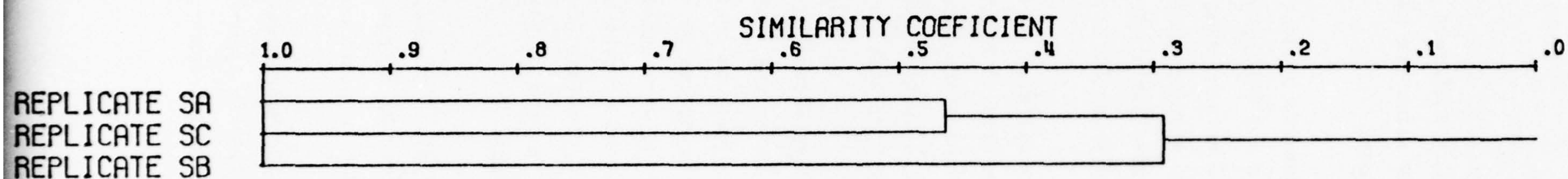


Figure 87.
STATION S2-IAAP BENTHOS-COMPARISON OF NAT. SUB. SURBER REPS. (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



replicate was quite different from the remaining two, however this did not significantly alter the calculated mean species diversity at the respective stations.

Mean species diversity of benthic macroinvertebrates collected by the surber method did not change greatly between stations (Figure 79). An increase occurred between station B3 and station B4, and species diversity then decreased at station B5. Between stations B5 and B8 species diversity changed very little (Table 102; Figure 79). Species evenness (Table 103; Figure 79) showed a parallel trend with species diversity.

Species diversity differed considerably between the two Spring Creek stations when compared to the Hester-Dendy plate and ponar sample trends. Instead of an increase occurring from station S1 to station S2, a small decrease was seen. Species evenness did not parallel species diversity; it increased 0.01 from station S1 to S2 (Table 103; Figure 79).

Benthos species diversity from replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in four stations being grouped due to the relatively high species similarity between them. These were station B3, B4, B5 and B8. Stations B3 and B4 were similar at 69 percent with station B5 being similar at 67 percent (Figure 88). Proximal stations are expected to be similar if no detrimental effects from waste effluents exist, which is indicated for these three stations.

A second group of stations, B7, S1, and S2 were similar at the 62 percent level. Station B6 is the most different of any station, being similar to the other stations above 40 percent (Table 104; Figure 88).

Percent dominance of macroinvertebrate species occurrence was calculated from the species list in Appendix XVI. There were three taxa of benthic macroinvertebrates which comprised 60 percent of the population at

Table 104. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATE (SURBER METHOD) REPLICATES AT EACH STATION.
IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA MAY-JUNE 1975

	Brush Creek						Spring Creek	
Stations	B3	B4	B5	B6	B7	B8	S1	S2
B3	1.000							
B4	0.689	1.000						
B5	0.684	0.648	1.000					
B6	0.533	0.464	0.455	1.000				
B7	0.652	0.628	0.613	0.464	1.000			
B8	0.590	0.568	0.610	0.434	0.589	1.000		
S1	0.580	0.585	0.595	0.430	0.642	0.529	1.000	
S2	0.576	0.570	0.570	0.386	0.595	0.467	0.636	1.000

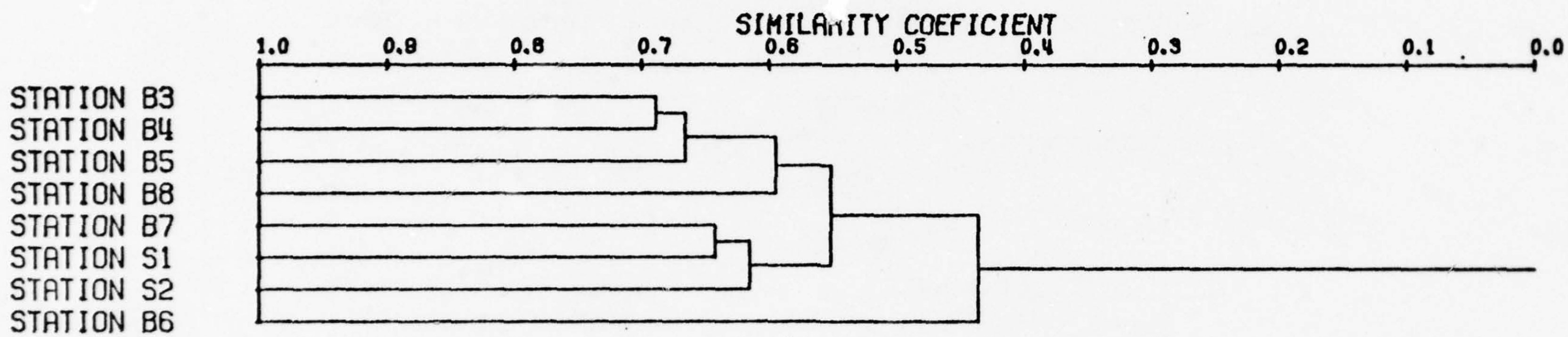
Figure 88.

IAAP BENTHOS-STATION COMPARISON OF NAT. SUB.-SURBER REP. (MAY-JUNE 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



station B3. These were *Cricotopus* sp. (34 percent), *Asellus* sp. (14 percent) and *Physa integra* (12 percent).

At station, B4, *Simulium* sp. was dominant (23 percent). Co-dominant was *Cricotopus* sp. at 16 percent. Two other taxa, *Hydropsyche* sp. (14 percent) and *Cheumatopsyche* sp. (12 percent) were common. Thus, these four taxa comprised 65 percent of the population.

Three taxa were present at station B5, comprising 59 percent of the total benthos community structure. *Simulium* sp. increased from 23 percent to 35 percent while *Cricotopus* sp. decreased from 16 percent to 12 percent. *Hydropsyche* sp. was also present at 12 percent.

Agraylea multipunctata (20 percent) was the most abundant species at station B6. Other taxa occurring were *Cheumatopsyche* sp. (19 percent) and *Asellus* sp. (12 percent) together comprising 31 percent of the population.

At station B7 three taxa comprised 70 percent of the macroinvertebrate association. These were *Cryptochironomus* sp. (31 percent), *Cricotopus* sp. (30 percent) and *Simulium* sp. (9 percent).

Station B8 also had three taxa comprising 60 percent of the benthic community. A new taxon, *Baetis* sp. (20 percent), was co-dominant with *Cricotopus* sp. (21 percent). *Agraylea multipunctata* recurred at 19 percent.

Station S1 of Spring Creek had four taxa comprising 55 percent of the species complex. *Agraylea multipunctata* was most dominant at 20 percent. *Cheumatopsyche* sp. (12 percent), *Asellus* sp. (12 percent) and *Cricotopus* sp. (11 percent) were next in decreasing order.

At station S2, 42 percent of the macroinvertebrate population was comprised of three taxa. Twenty-four percent was *Cricotopus* sp. compared

to the 11 percent at Station S1. Asellus sp. was present at 10 percent and Stictochironomus sp. at 8 percent.

To summarize Appendix XVI for surber species data, the Brush Creek stations averaged 27 total taxa. Stations S1 and S2 of Spring Creek both had 28 total taxa represented.

Discussion of Results

Species Occurrence on Artificial Substrates (May-June)-

Benthic macroinvertebrate species diversity increased with distance downstream. Species diversity did not follow any specific chemical trend. Low species diversities were observed at stations B2, B3, and B5, where the Chironomidae dominated. This family is considered in the literature to be facultative to intolerant of organic pollution[36].

On the other hand, stations B6, B7, and B8 showed high species diversities with Agraylea sp., an intolerant organism[36], dominating. Most taxa occurring at a significant level at any station were facultative to intolerant of organic pollution. The most important aspect observed in the trend in species diversity occurred at stations B5 and B7, where a decrease in diversity occurred. At both of these stations aqueous and sediment TNT was found to be high.

This trend observed in the mean diversity on artificial substrates may have resulted from the natural characteristics of the creek combined with the observed TNT levels. However, it should be pointed out that the substrate used as artificial substrates is selective to certain types of fauna, incubation periods vary in different bodies of water and it is dependent on chance colonization by drifting or swimming organisms[36].

The proximal stations on Brush Creek were similar above 53 percent except for station pairs B5 - B6 and B7 - B8. Station B5, located below industrial effluent I5 and I7, was similar to station B6, which was not directly effected by any industrial wastes, at a somewhat lower level of 47 percent. Similarity between station pair B7 - B8 was 49 percent. Station B7 received the domestic sewage treatment plant wastes while station B8 was the recovery zone of Brush Creek.

This comparison between adjacent stations, showed a high level of similarity between all stations. Indications are that any effects on the benthic community caused by industrial wastes are minimal and of short term duration. This conclusion is based on the fact that species diversity, species dominance and similarity between stations show recovery of the benthic macroinvertebrate population within the study area.

Spring Creek species diversity increased between station S1 and S2. The low diversity at station S1 was possibly caused by siltation of the stream bed due to construction work upstream. Taxa that occurred at both stations were facultative to intolerent.

Species Occurrence on Natural Substrates (May-June) -
Ponar samples - Species diversity and species occurrence of benthic macroinvertebrates from ponar samples are dependent upon the chemistry of the sediments because they are in direct contact with the soft substrate of the creek. Sediments of this type are more susceptible to sorbtion of various materials. Mean species diversity showed an irregular pattern between stations.

Two important diversity trends occurred within Brush Creek. The first was a large decrease that occurred between station B1 and station B4. Station B1, which possessed the highest diversity, relates to its conditions as a reference station (i.e., there were no industrial wastes influencing the station on its upstream side).

The remaining three stations exhibited decreased diversity, corresponding to the large increase in sediment TNT. This is particularly true of station B4 which was characterized by one of the lower diversity values and the highest sediment TNT level in Brush Creek.

The second important trend occurred between stations B5 and B8. The shifts that occurred between stations are uncertain. The increase in diversity from station B4 to station B5 corresponds to the decrease in sediment TNT, however the sharp decrease at station B6 does not. TNT levels in the sediment were very low at this station. It is possible that some inhibitory factor(s) or natural limiting factor may be causing this drastic change in diversity.

Diversity then increased at station B7 where nutrient levels were high, possibly accounting for more abundant food sources for the invertebrate community. From station B7 to station B8 a small decrease occurred.

Species occurrence and dominance showed Brush Creek to have a Chironomidae/ Tubificidae complex. These taxa ranged from intolerent to tolerent of organic pollution[36]. At the stations where diversity decreased or was relatively low (i.e., B3, B4, B6, B8) Stictochironomus sp., an intolerant chironomid, was the most dominant taxon. The reason for the occurrence of an intolerant organism such as this in a community of low diversity is uncertain. There is not sufficient literature on the autecology of this organism to be able to hypothesize other causative factors for its presence in such a situation.

Proximal station similarities was very high, with station pairs B1 - B2 and B7 - B8 being less similar. As previously explained for the artificial substrates,these stations (i.e. B1 and B8) were reference and recovery zones, respectively, and their difference to the adjacent stations suggest the macroinvertebrate community is being affected by the industrial effluents in the intervening reaches of Brush Creek.

Mean species diversity increased between stations S1 and S2 of Spring Creek. Siltation from construction upstream covered the sediments and probably caused unsatisfactory conditions for the survival of many more species at station S1.

Surber square foot samplers - Species diversity of benthic macroinvertebrates collected by the surber sampler did not shift significantly between stations. This was shown by the analysis of variance test. From this observation it can be concluded that the population in the riffle area (characterized by hard surfaces) were less affected by wastes than the pool populations present in soft, sandy sediments.

Species that occurred at the stations, were faculatative to intolerent[36] indicating stream conditions were healthy. Similarity between proximal stations was also high (above 46 percent).

From the macroinvertebrate community analyzed on natural and artificial substrates it can be concluded that organisms in direct contact with the sediments are affected greatly by the industrial wastes. Some unexplainable inhibitory factor (i.e., other than TNT) may also limit the population.

Artificial substrates indicate a small effect from the industrial wastes however recovery is seen to be occurring. On the other hand, macroinvertebrates within the riffle areas do not appear to be affected.

Results

Species Occurrence on Artificial Substrates (October) - The trend of benthic macroinvertebrate species diversity on artificial substrates for Brush and Spring Creeks showed less variation between stations when compared to the May-June results. Replication of the three samples collected at each station was sometimes variable. Table 105and106 and Figure 89 show the values of species diversity and evenness

Table 105. SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. HESTER-DENDY PLATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. OCTOBER 1975.

	Brush Creek								Spring Creek	
Sample Replicates	B1*	B2	B3	B4	B5	B6	B7	B8	S1	S2
1		1.10	1.57	1.72	1.91	1.64	1.93	1.28	1.72	1.87
2		1.71	1.49	1.88	2.06	1.96	1.95	1.26	1.61	1.73
3		1.77	1.56	1.75	1.57	1.89	2.02	1.44	1.10	2.05
$\overline{X}$		1.53	1.54	1.78	1.85	1.83	1.97	1.33	1.48	1.88
S^2		0.139	0.002	0.007	0.064	0.028	0.002	0.009	0.109	0.025
S		0.372	0.042	0.084	0.253	0.167	0.045	0.097	0.330	0.157

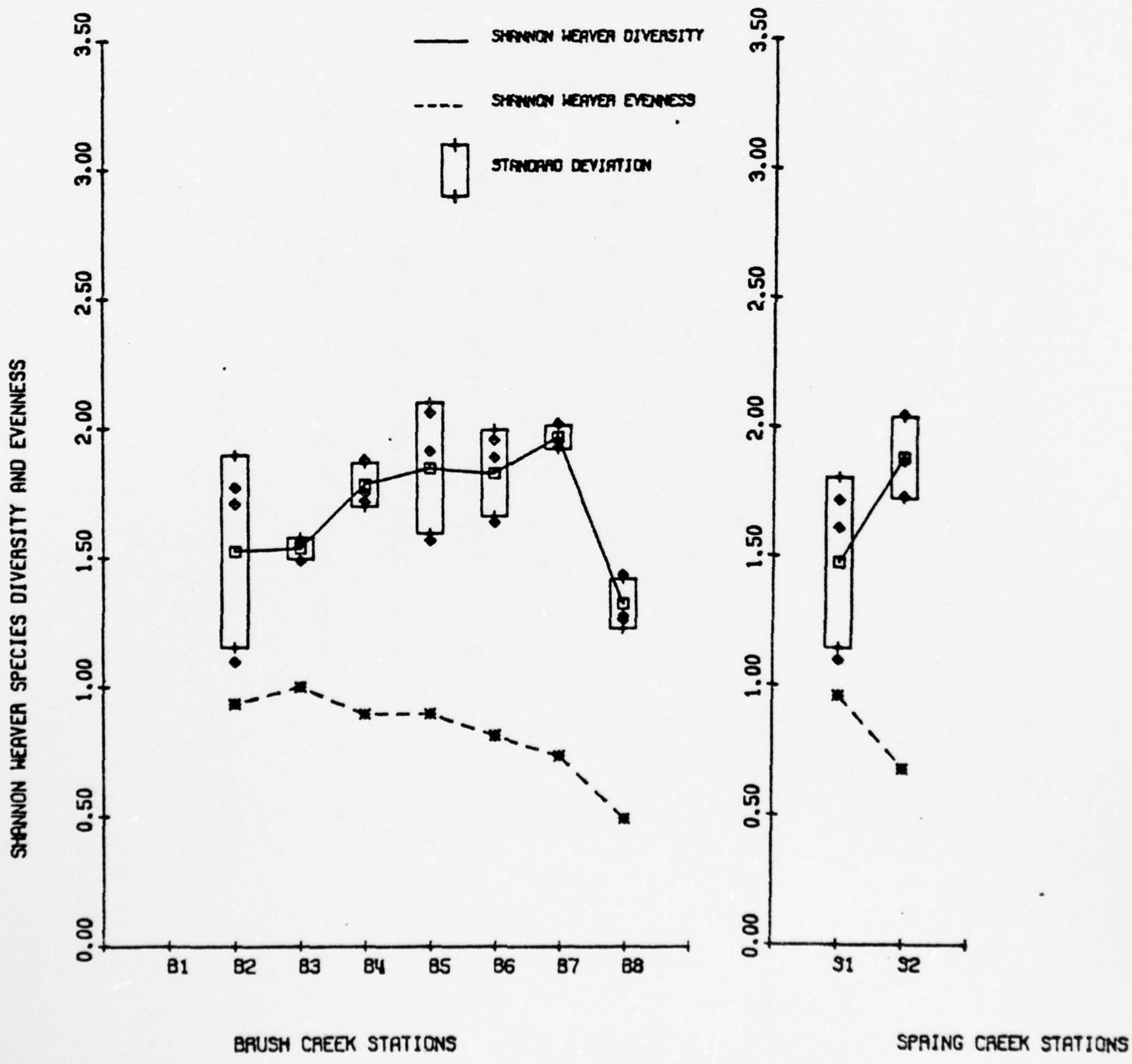
*No collection due to extremely shallow water

Table 106. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. HESTER-DENDY PLATES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. OCTOBER 1975.

	Brush Creek								Spring Creek	
Sample Replicates	B1*	B2	B3	B4	B5	B6	B7	B8	S1	S2
1		1.00	0.71	0.88	0.92	0.79	0.73	0.46	0.88	0.66
2		0.95	0.83	0.90	0.90	0.89	0.70	0.48	1.00	0.62
3		0.85	0.71	0.90	0.88	0.76	0.77	0.54	1.00	0.76
$\overline{X}$		0.94	0.75	0.90	0.90	0.81	0.73	0.49	0.96	0.68
S^2		0.006	0.005	0.000	0.000	0.005	0.001	0.002	0.005	0.005
S		0.076	0.070	0.011	0.022	0.069	0.030	0.044	0.068	0.068

* No collection due to extremely shallow water

Figure 89.
IAAP BENTHOS- DIVERSITY OF ART. SUB. (OCT 75)



calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

1) Samples were not collected and analyzed for species occurrence at station B1 for the same reason described previously, i.e., low water levels which insufficiently covered the Hester-Dendy plates. Refer back to May-June results for further explanation.
2) At station B2 the species distribution of the three replicates was similar above the 20 percent level (Figure 90), with two replicates similar above 45 percent. Species diversity decreased from 1.53 to 1.41 when the most different replicate was ignored, however, this difference of 0.12 is very small and probably insignificant.
3) The results of sample replicates at station B3 was more similar. Three replicates were similar at 25 percent while two replicates were similar at 44 percent (Figure 91). The mean species diversity did not change (1.54).
4) The three replicate samples at station B4 were similar above the 40 percent level (Figure 92). Two of these replicates were similar above 45 percent, however, mean species diversity (1.78) did not change significantly when the most different replicate was ignored.
5) At station B5 the three replicates were similar below 30 percent, with two replicates similar at the 50 percent level (Figure 93). The mean species diversity (1.85) was representative of the benthic macroinvertebrate community.
6) Station B6 showed a similarity above 30 percent for the three replicate samples (Figure 94). Mean species diversity remained at 1.83 even when the two most similar replicates (44 percent) were used to calculate diversity.

Figure 90.

STATION B2-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

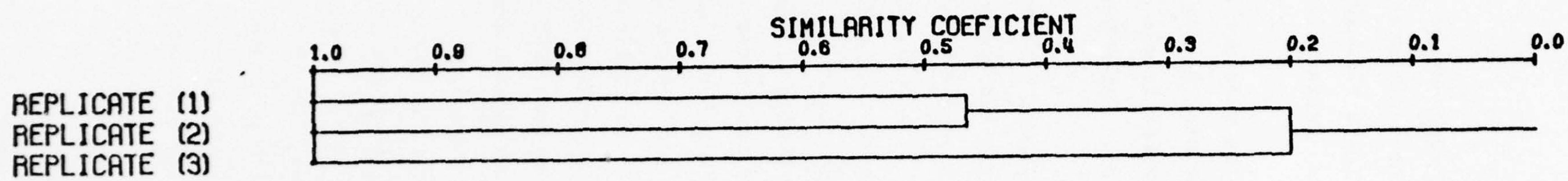


Figure 91.
STATION B3-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

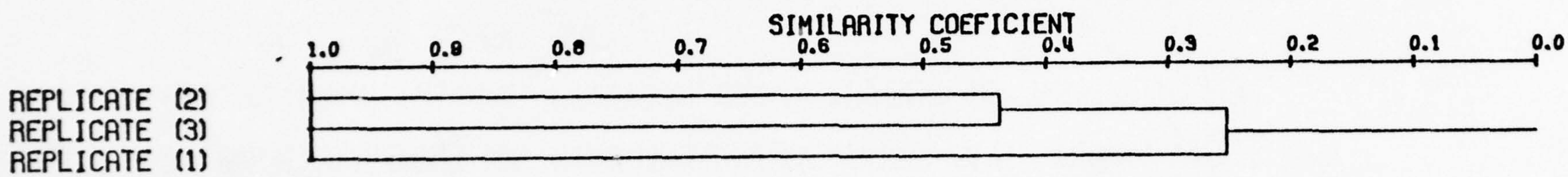


Figure 92

STATION B4-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

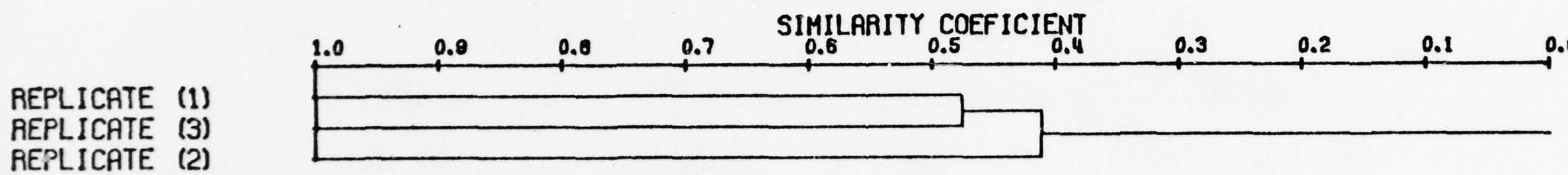


Figure 93.

STATION B5-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

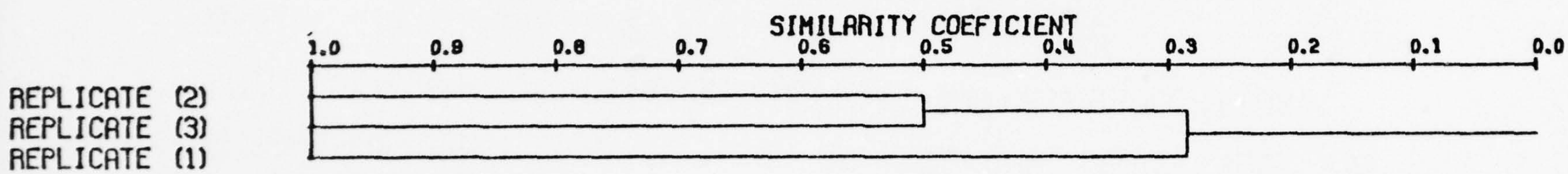


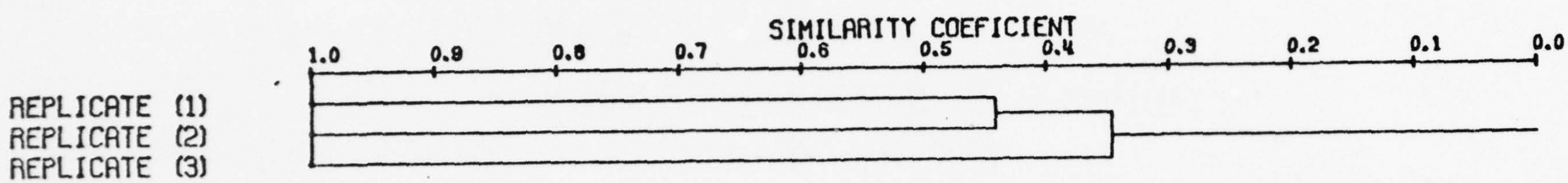
Figure 94.

STATION B6-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



7) Mean species diversity was 1.97 for the combined three replicates at station B7. The replicates were similar between 30 and 40 percent (Figure 95).

8) Replication of benthic macroinvertebrate species associations at station B8 (Figure 96) was similar above the 35 percent level. Ignoring the most different replicate, species diversity decreased from 1.33 to 1.27, an insignificant change.

9) Station S1 of Spring Creek had its three replicates similar above 25 percent (Figure 97). Two replicates were similar at 45 percent. The mean species diversity was 1.48 (Table 105) but would be somewhat lower at 1.35 if the most different replicate was ignored. This difference of 0.13 is most likely not significant.

10) At station S2 the benthic macroinvertebrate species distribution of the three replicates was similar at the 40 percent level, with two being more similar above 45 percent (Figure 98). Mean species diversity was 1.88.

The application of species diversity and coefficient of similarity to the replicate samples at each station, particularly the coefficient of similarity, indicates whether or not a sufficient sample has been taken to adequately describe the existing community. It was shown that sometimes one of the three replicate samples was quite different from the remaining samples, however the presence or absence of its species data had little effect on the estimation of the benthic community structure, i.e. species diversity. Thus, the inclusion of all replicate samples on a combined basis at each station provided a broader species complex from which station-to-station comparisons were made.

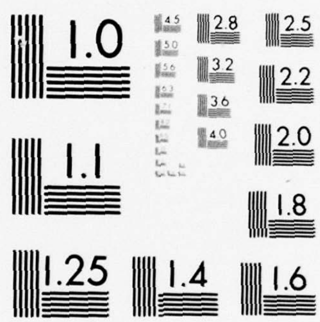
Mean species diversity of benthic macroinvertebrates collected from artificial substrates remained the same at stations B2 and B3 (1.53 and 1.54 respectively). A small increase occurred between station B3 and station B4 (Table 105; Figure 89). Stations B5 and B6 had species diversity at the same level as station B4, with a slight increase in

AD-A036 776 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITI--ETC(U)
NOV 76 S L SANOCKI, P B SIMON, R L WEITZEL DAMD17-75-C-5046

UNCLASSIFIED NL

5 OF 5
AD
A036776

END
DATE
FILMED
4-77



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 95.
STATION B7-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

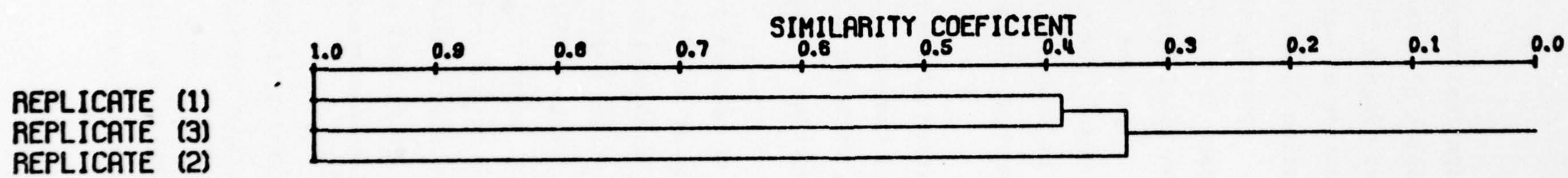


Figure 96.
STATION B8-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

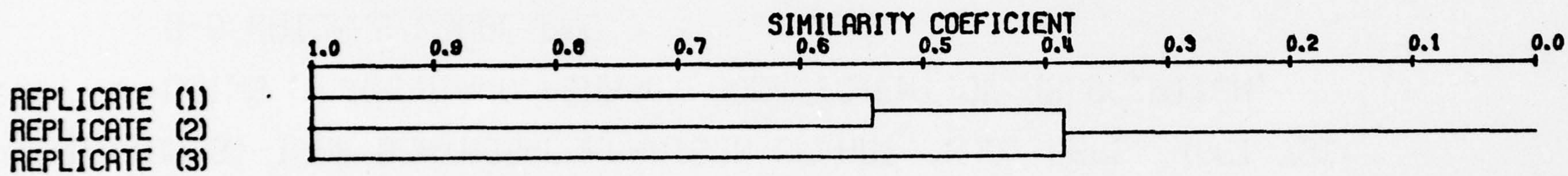


Figure 97.

STATION S1-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

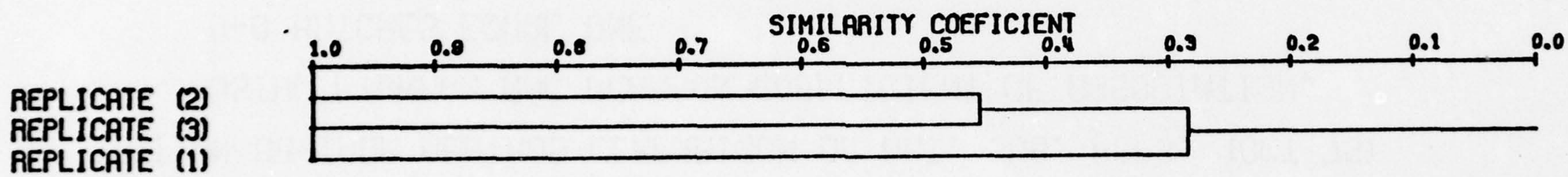
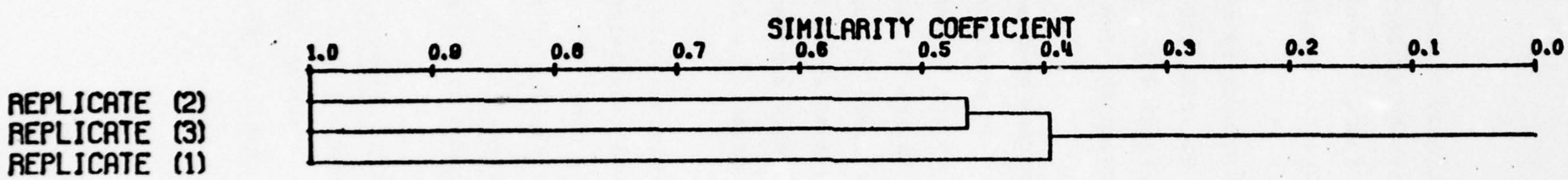


Figure 98.
STATION S2-IAAP BENTHOS-COMPARISON OF ART. SUB. REPS. (OCT 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT



species diversity occurring at station B7. A significant change in species diversity (a decrease from 1.97 to 1.33) occurred between stations B7 and B8. Species evenness (Table 106; Figure 89) did not show a parallel trend with species diversity.

Mean species diversity differed between the two Spring Creek stations. An increase occurred between station S1 (1.48) and station S2 (1.88) (Table 105; Figure 89). Species evenness, on the other hand, showed a decrease between the two stations (Table 106; Figure 89).

Macroinvertebrate species data from replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in stations B2 and B4 being similar at 82 percent. Stations B8 and S2 were similar above 50 percent. The remaining stations (B3, S1, B6, B5, and B7) were similar to station B2 and B4 in order of highest similarity. All stations were similar above 45 percent. Refer to Table 107 and Figure 99 for more detailed information.

Percent dominance of the macroinvertebrate species occurring on artificial substrates was calculated from the species list in Appendix XVIII. During October 1975, there were four taxa of benthic macroinvertebrates which comprised 69 percent of the population at station B2. These were Palpomyia tibialis (25 percent), Pentaneura sp. (16 percent), Stictochironomus sp (14 percent) and Hemerodromia sp. (14 percent).

At station B3, Palpomyia tibialis remained the primary dominant increasing from 25 percent to 40 percent. Chironomus sp. was co-dominant and made up 24 percent of the benthic population. Thus two taxa comprised 64 percent of the total community occurring on the Hester-Dendy plates.

Table 107. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATES SPECIES ASSOCIATIONS BASED ON COMBINED ARTIFICIAL SUBSTRATE REPLICATES AT EACH STATION.

IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS

BURLINGTON, IOWA. OCTOBER 1975

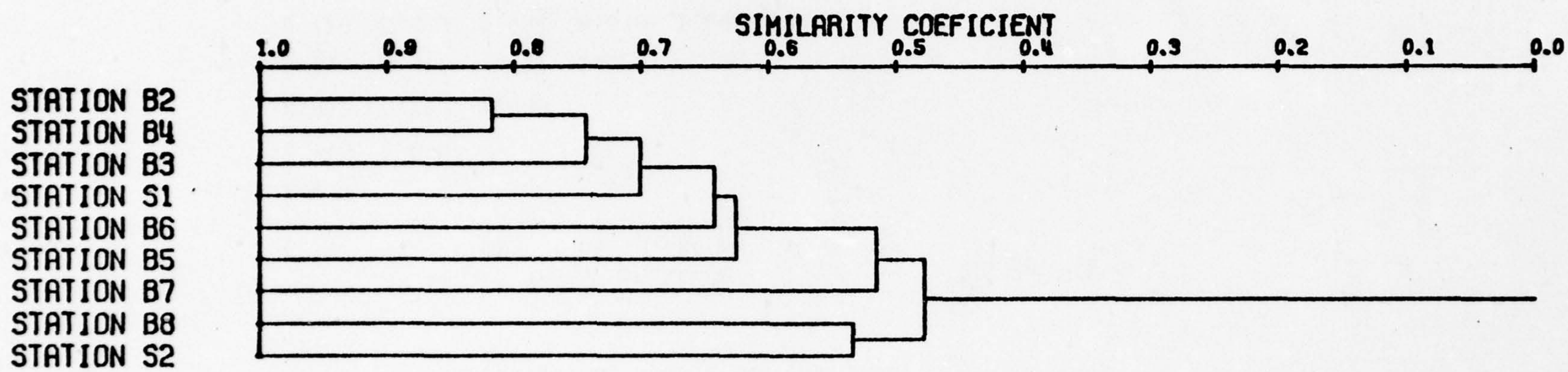
	Brush Creek							Spring Creek	
Stations	B2	B3	B4	B5	B6	B7	B8	S1	S2
B2	1.000								
B3	0.746	1.000							
B4	0.817	0.740	1.000						
B5	0.742	0.611	0.657	1.000					
B6	0.719	0.629	0.694	0.630	1.000				
B7	0.563	0.532	0.558	0.496	0.553	1.000			
B8	0.564	0.521	0.584	0.472	0.512	0.424	1.000		
S1	0.715	0.677	0.733	0.588	0.617	0.489	0.568	1.000	
S2	0.578	0.573	0.634	0.462	0.495	0.475	0.534	0.649	1.000

Figure 99.
IAAP BENTHOS-STATION COMPARISON OF ART. SUB.-COMBINED REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



Three taxa present at station B4 comprised 60 percent of the total benthic community structure. _Stictochironomus_ sp. was dominant at 27 percent. The two other taxa present were _Dicrotendipes_ sp. (23 percent) and _Chironomus_ sp (10 percent).

Cricotopus sp. (22 percent) was the most dominant taxon of the three that comprised 49 percent of the benthic macroinvertebrate population at station B5. _Hemerodromia_ sp. and _Pentaneura_ sp. were present at 17 and 10 percent, respectively.

At station B6, four taxa comprised 72 percent of the population, with _Stictochironomus_ sp. (27 percent) being dominant. The co-dominant taxon was _Pentaneura_ sp. (20 percent). Other commonly occurring taxa were _Palpomyia tibialis_ (14 percent) and the oligochaete, _Limnodrilus_ sp. (11 percent).

Station B7 had three taxa which together comprised 66 percent of the macroinvertebrate association. _Stictochironomus_ sp. increased slightly to 30 percent and remained dominant. _Pentaneura_ sp. (22 percent) increased two percent with _Chironomus_ sp. being present at 14 percent.

Stictochironomus sp. increased two-fold at station B8 (30 percent to 65 percent). _Cricotopus_ sp. occurred at 14 percent. These two species together comprised 79 percent of the macroinvertebrate population at this station.

The two Spring Creek stations had a very different population dominance. _Chironomus_ sp. was the most dominant (23 percent) of three taxa which comprised 59 percent of the population at station S1. The two other taxa that were common at this station were _Asellus_ sp. (20 percent) and _Stictochironomus_ sp. (16 percent).

At station S2, 68 percent of the population was comprised of four taxa. Twenty-nine percent was Dicrotendipes sp. and 19 percent was Stictochironomus sp. The two other taxa were Chironomus sp. and Stenonema (interpunctatum group) both comprising 10 percent of the total population.

Differences in benthic macroinvertebrate community structure and similarity which occurred between sampling stations were the result of the occurrence, loss and recurrence of uncommon and rare species. To summarize Appendix XVIII, the total number of taxa found at each station increased with distance downstream. Station B2 had 9 taxa, station B3 had 15 taxa and 10 taxa were found at station B4. Stations B5 and B6 had 17 and 18 taxa, respectively. The most taxa found was at stations B7 and B8 (averaging 24 taxa). Station S1 and station S2 had 11 and 22 total taxa, respectively.

Species Occurrence on Natural Substrates (October) -
Samples collected from natural substrates include samples taken with a petite ponar and surber square foot sampler. Species data from these two sample types were analyzed for species diversity, evenness, species association and species dominance.

Ponar samples - Two replicate ponar samples were taken at each sampling station except for those stations (B2, B7, S1 and S2) which did not have riffles suitable for sampling with the surber square foot sampler. These stations had four replicate ponars collected and analysed for species occurrence.

Mean species diversity of the two or four replicate samples at each station showed an irregular pattern. Table108 and109 and Figure100 show the values of species diversity and evenness calculated for each sample replicate, as well as mean and standard deviation of the replicates for each station. Replication of the two or five samples for each station was sometimes variable. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Using this means of analysis the following were noted:

Table 108. SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FOUR REPLICATE NATURAL SUBSTRATES-PONAR. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA, OCTOBER-NOVEMBER, 1975.

	Brush Creek								Spring Creek	
Sample Replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	NS	1.26	1.08	0.37	0.93	1.40	0.54	0.71	1.30	1.17
2	NS	1.70	0.37	0.43	1.04	1.58	0.86	0.79	1.38	1.74
3	NS	1.16	NS	NS	NS	NS	0.96	NS	1.09	1.79
4	NS	1.33	NS	NS	NS	NS	0.83	NS	0.84	1.36
$\overline{X}$	NS	1.362	0.72	0.40	0.98	1.49	0.80	0.75	1.15	1.52
S^2	NS	0.054	0.252	0.002	0.006	0.016	0.033	0.003	0.059	0.089
S	NS	0.233	0.502	0.042	0,081	0.128	0.181	0.058	0.243	0.299

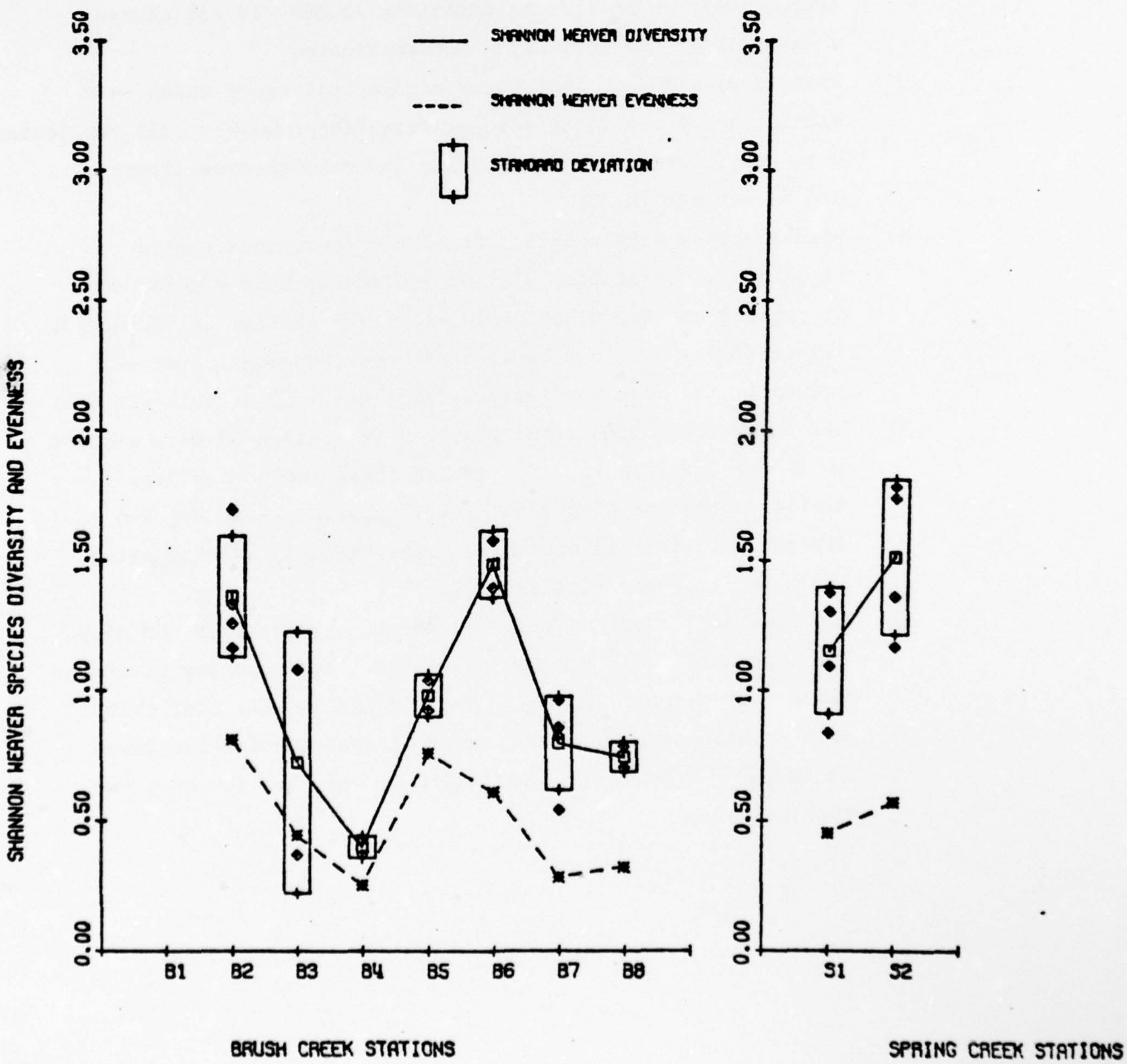
Note: NS = no sample due to low water

Table 109. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FOUR REPLICATE NATURAL SUBSTRATES-PONAR. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. OCTOBER-NOVEMBER, 1975.

	Brush Creek								Spring Creek	
Sample Replicate	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	NS	0.78	0.56	0.27	0.58	0.61	0.20	0.31	0.52	0.47
2	NS	0.95	0.34	0.24	0.95	0.62	0.30	0.34	0.51	0.60
3	NS	0.56	NS	NS	NS	NS	0.35	NS	0.46	0.70
4	NS	0.96	NS	NS	NS	NS	0.29	NS	0.32	0.52
$\overline{X}$	NS	0.81	0.45	0.25	0.76	0.61	0.28	0.32	0.45	0.57
S^2	NS	0.035	0.024	0.000	0.069	0.000	0.004	0.001	0.009	0.010
S	NS	0.187	0.154	0.019	0.262	0.006	0.062	0.025	0.095	0.100

Note: NS = no sample due to low water

Figure 100.
IAAP BENTHOS- DIVERSITY FOR NAT. SUB. PONAR (OCT 75)



1) No samples (ponar or surber) for natural substrates were collected at station B1 because of the very dry conditions which occurred. At the time of the survey this station was non-existant.

2) Of the four replicates collected at station B2, one was most different. Three replicates were similar at 49 percent while the similarity between all four replicates was 25 percent (Figure 101). Mean species diversity (1.36) did not change when ignoring the most different replicate.

3) Station B7 also had four ponar sample replicates which were similar above the forty percent level (Figure 102). All replicates were very close in similarity and the mean species diversity did not change (0.80).

4) Both stations within Spring Creek had four ponar sample replicates. At station S1, two replicates were similar at 68 percent and two other replicates were similar at 45 percent (Figure 103). All four replicates were then similar at 40 percent. The mean species diversity was 1.15 at this station.

5) All ponar replicates (four samples) at station S2 were similar at 35 percent (Figure 104). Two of these replicates were similar above the 65 percent level, however, mean species diversity (1.52) did not change significantly when ignoring the most different replicate(s).

6) The remaining stations (B3, B4, B5, B6 and B8) each had only two replicate ponar samples collected. Mean species diversity values are shown in Table 108 and Figure 100. The similarity values between the two replicates of each station are given in Table 110. Note that similarity is very low for only two replicates.

Figure 101.
STATION B2-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (OCT 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

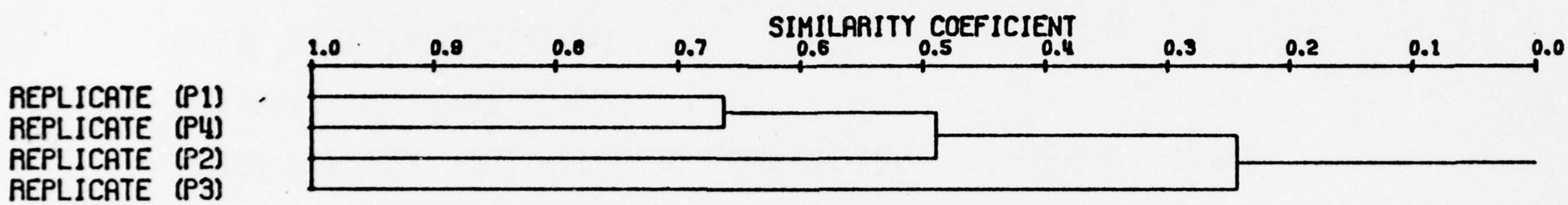


Figure 102.

STATION B7-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

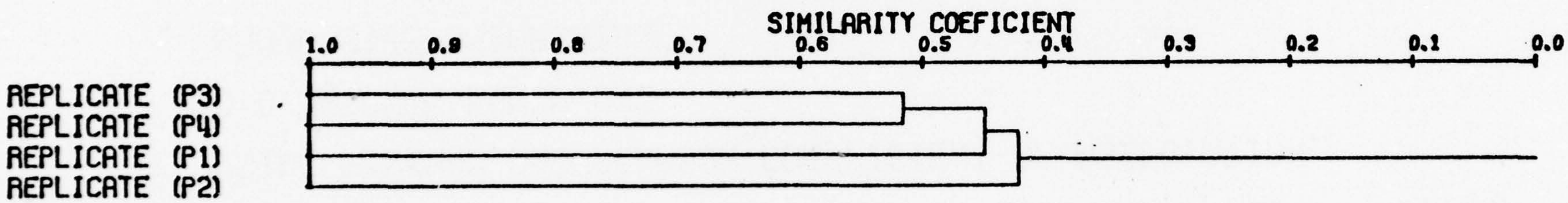


Figure 103.

STATION S1-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

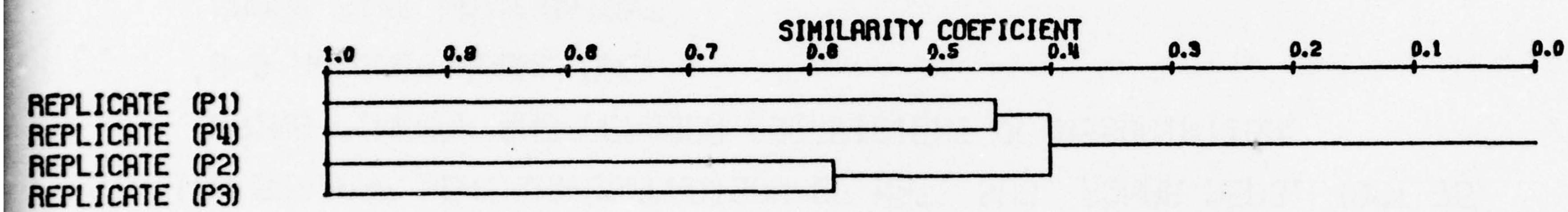


Figure 104

STATION S2-IAAP BENTHOS-COMPARISON OF NAT. SUB. PONAR REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

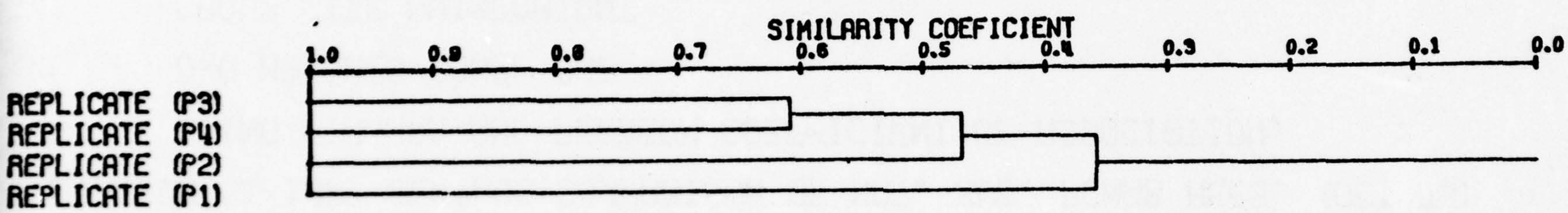


Table 110. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATION BASED ON TWO REPLICATE PONAR SAMPLES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. OCTOBER, 1975.

Stations	B3	B4	B5	B6	B8
	0.215	0.354	0.191	0.241	0.240

Mean species diversity of benthic macroinvertebrates collected from natural substrates (ponar method) showed a large decrease between station B2 and station B4. Station B4 had the lowest mean species diversity of the Brush Creek stations. A sharp increase occurred between stations B4 and B6 with station B6 having a species diversity value similar with station B2 (Table 108; Figure 100). A decrease was seen between station B6 and station B7. Station B8 remained at the same level as station B7. Species evenness (Table 109; Figure 100) paralleled species diversity.

An increase in species diversity occurred between stations S1 and S2 (1.15 to 1.52) of Spring Creek. Species evenness (Table 109; Figure 100), also showed a parallel trend to species diversity.

Macroinvertebrate species data from the ponar replicate samples were combined and compared between stations using the coefficient of similarity. The application of the Pinkham and Pearson coefficient of association resulted in station B7 being most different from all other station benthos populations, which is probably a result of this station being below the domestic sewage treatment plant (Table 110 Figure 105).

Stations B8 and S1 were similar at 65 percent, which is a good indication that Brush Creek is recovering from any possible effects caused by the industrial wastes. The Brush Creek stations B2, B3, B4, B5, B6 were all grouped due to the relatively high similarity between them. They were similar above 65 percent. Since these stations are located in

Table 111. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATE (PONAR METHOD) REPLICATES AT EACH STATION.
IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS, BURLINGTON IOWA. OCTOBER 1975

Stations	Brush Creek B2	B3	B4	B5	B6	B7	B8	Spring Creek S1	S2
B2	1.000								
B3	0.708	1.000							
B4	0.693	0.828	1.000						
B5	0.758	0.847	0.819	1.000					
B6	0.689	0.668	0.644	0.718	1.000				
B7	0.398	0.415	0.438	0.439	0.363	1.000			
B8	0.662	0.652	0.677	0.715	0.574	0.394	1.000		
S1	0.545	0.553	0.551	0.602	0.516	0.338	0.646	1.000	
S2	0.520	0.459	0.483	0.539	0.496	0.361	0.589	0.552	1.000

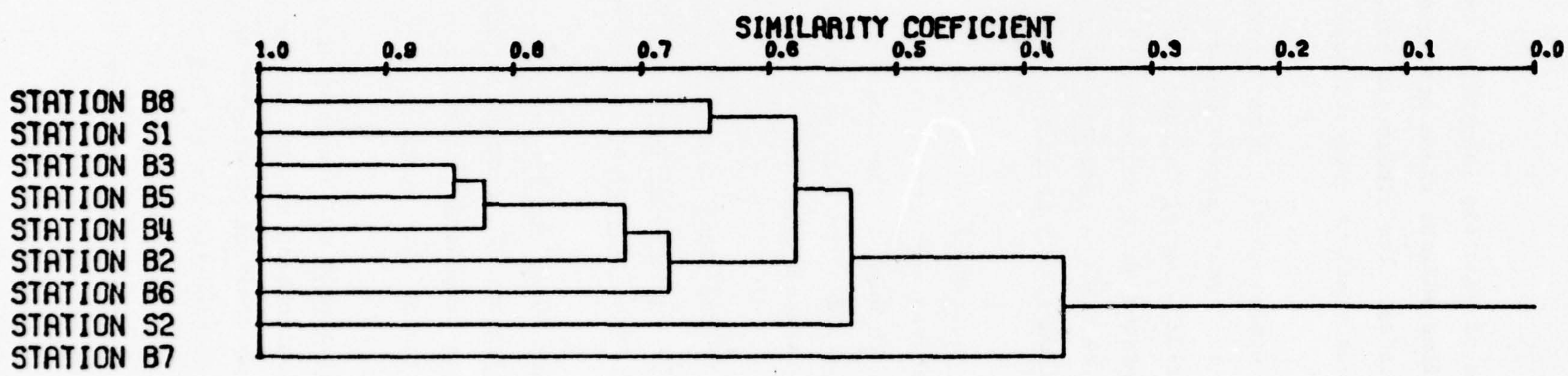
Figure 105

IAAP BENTHOS-STATION COMPARISON OF NAT. SUB. PONAR REPS. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



the area of greatest industrial waste discharge the similarity of benthos populations between these stations may reflect the possible affects of these wastes. The similarity between the reference stations and most downstream stations suggests population recovery.

Percent dominance of the macroinvertebrate species occurring on natural substrates (ponar method) was calculated from the species list in Appendix XIX. During October 1975, there were two taxa of benthic macroinvertebrates which comprised 69 percent of the total population at station B2. These were Palpomyia tibialis (44 percent) and Limnodrilus sp. (25 percent).

At both station B3 and station B4, one taxon (Stictochironomus sp.) comprised the majority of the population. This same taxon also remained dominant throughout the remaining Brush Creek stations. Stictochironomus sp. comprised 83 percent and 92 percent of the population at stations B3 and B4, respectively.

Station B5 had three taxa that comprised 95 percent of the total benthic community. Stictochironomus sp. was present at 62 percent. The other two taxa were Chrysops sp. (18 percent) and Chironomus sp. (15 percent).

At station B6 Stictochironomus sp. comprised 53 percent of the population. Polypedilum sp. (17 percent) and Chrionomus sp. were also common. Thus, three taxa comprised 81 percent of the benthic macroinvertebrate association at this station.

Stictochironomus sp. occurred at both station B7 and B8 at 80 percent. The co-dominant at station B7 was Chironomus sp (10 percent). Limnodrilus sp. was co-dominant at station B8 at 10 percent also. Therefore, two taxa at stations B7 and B8 comprised 90 percent of the total population.

The Spring Creek stations had a very different population dominance. Station S1 had one species, Aulodrilus pluriseta, which comprised 73 percent of the population. At station S2 Aulodrilus pluriseta decreased

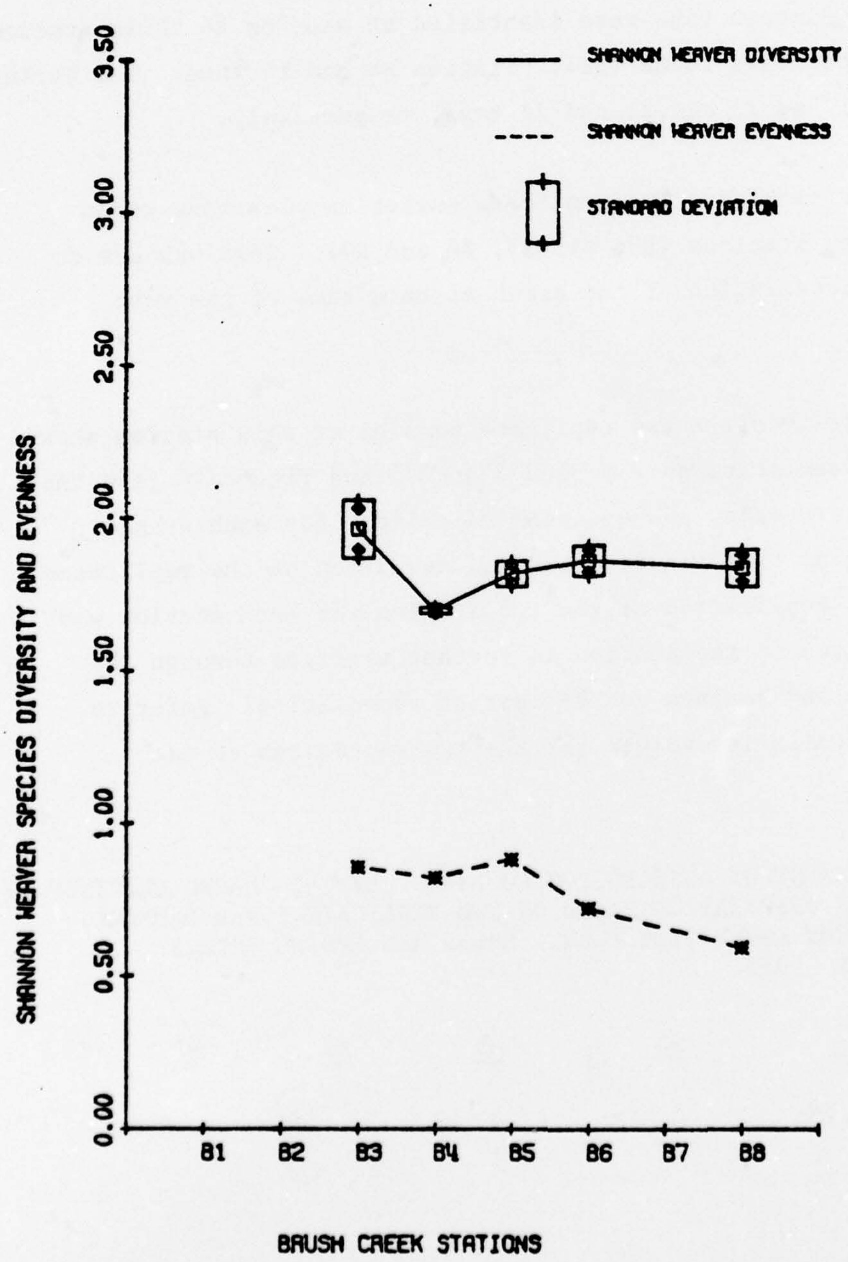
Table112. SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM TWO REPLICATE NATURAL SUBSTRATES-SURBER. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEK. BURLINGTON, IOWA. OCTOBER-NOVEMBER, 1975.

	Brush Creek								Spring Creek	
Sample Replicate	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	NS	NS	1.90	1.71	1.79	1.90	NS	1.80	NS	NS
2	NS	NS	2.03	1.69	1.85	1.83	NS	1.88	NS	NS
$\overline{X}$	NS	NS	1.97	1.70	1.82	1.86		1.84	NS	NS
S^2	NS	NS	0.009	0.000	0.002	0.003		0.004	NS	NS
S	NS	NS	0.095	0.010	0.043	0.050		0.061	NS	NS

Table 113. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM TWO REPLICATE NATURAL SUBSTRATES-SURBER. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. BURLINGTON, IOWA. OCTOBER-NOVEMBER, 1975.

	Stations									
Sample Replicates	B1	B2	B3	B4	B5	B6	B7	B8	S1	S2
1	NS	NS	0.79	0.88	0.82	0.68	NS	0.58	NS	NS
2	NS	NS	0.92	0.77	0.95	0.76	NS	0.61	NS	NS
$\overline{X}$	NS	NS	0.86	0.83	0.88	0.72	NS	0.60	NS	NS
S^2	NS	NS	.009	.006	.009	.003	NS	.000	NS	NS
S	NS	NS	.094	.075	.096	.055	NS	0.20	NS	NS

Figure 106
IAAP BENTHOS- DIVERSITY FOR NAT. SUB. SURBER (OCT 75)



in occurrence to 11 percent. The dominant at this latter station was Stictochironomus sp. (49 percent). Two other taxa, Chironomus sp. (16 percent) and Limnodrilus sp. (13 percent) were present. Thus, four taxa comprised 89 percent of the total population.

To summarize Appendix XIX,total number of taxa varied between the stations of Brush Creek. Station B2 had 12 taxa while stations B3, B4, and B5 averaged 7 taxa. Sixteen taxa were identified at station B6 while station B7 recorded the most taxa found (31). Station B8 had 14 taxa. The Spring Creek stations, S1 and S2 had 21 and 24 taxa, respectively.

Surber square foot samples - Two replicate surber samples were taken at five Brush Creek stations (B3, B4, B5, B6 and B7). This was due to the low flow characteristics of the creek at this time of the year (October).

Mean species diversity of the two replicate samples at each station showed little change between stations. Table 112 and 113 and Figure 106 give the values of species diversity and evenness calculated for each sample replicate, as well as the mean and standard deviation of the replicates for each station. Replication of the two samples for each station was very low. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of association. Refer to Table 114 for the similarity values for the two replicates at each station.

Table 114. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATION BASED ON TWO REPLICATE PONAR SAMPLES. IOWA ARMY AMMUNITION PLANT. BRUSH AND SPRING CREEKS. OCTOBER 1975.

Stations	B3	B4	B5	B6	B8
	0.136	0.228	0.308	0.298	0.326

A decrease occurred in mean species diversity between station B3 and station B4. Diversity then increased at station B5 where the remaining stations showed diversities at a similar value (Table 112; Figure 106). Species evenness did not parallel the species diversity trend (Table 113; Figure 106).

Individual species data from replicate samples were combined and compared between stations using the coefficient of similarity. This resulted in the recovery zone being the least similar to any of the other four stations (28 percent) (Table 115; Figure 107). Stations B4 and B5 were most similar at 66 percent, which is a good indication that the industrial wastes discharged between these stations are not drastically affecting the macroinvertebrate population, i.e. under favorable conditions proximal stations are expected to be similar. Station B3 was similar to stations B4-B5 at 62 percent and to station B6 at 50 percent.

Percent dominance of benthic macroinvertebrate species occurrence at the five stations mentioned previously, was calculated from the species list in Appendix XIX. There were three taxa that comprised 52 percent of the population at station B3. These were *Cricotopus* sp. (30 percent), *Hemerodromia* sp. (12 percent) and *Agria* sp. (10 percent).

At station B4, *Cricotopus* sp. decreased to 17 percent, while *Hemerodromia* sp. increased to 38 percent. A usually uncommon taxon, *Chrysops* sp., was present at 16 percent. Thus three species comprised 71 percent of the total population at this station.

Three taxon present at station B5 comprised 73 percent of the total community structure. *Chrysops* sp. increased from 16 percent to 33 percent and became the dominant. Co-dominant was *Cricotopus* sp. at 20 percent and *Hemerodromia* sp. was present at 12 percent.

Cricotopus sp. (39 percent) was the most dominant taxon of the four that comprised 81 percent of the macroinvertebrate population at station B6. The other three taxa were *Chrysops* sp. (16 percent), *Hydropsyche* sp. (16 percent) and *Hemerodromia* sp. (10 percent).

Table 115. COEFFICIENT OF ASSOCIATION COMPARING BENTHIC MACROINVERTEBRATE SPECIES ASSOCIATIONS BASED ON COMBINED NATURAL SUBSTRATE (SURBER METHOD) REPLICATES AT EACH STATION.
IOWA ARMY AMMUNITION PLANT. BRUSH CREEK, BURLINGTON, IOWA.
OCTOBER 1975

Stations	B3	B4	B5	B6	B8
B3	1.000				
B4	0.657	1.000			
B5	0.595	0.670	1.000		
B6	0.500	0.504	0.520	1.000	
B8	0.236	0.257	0.302	0.311	1.000

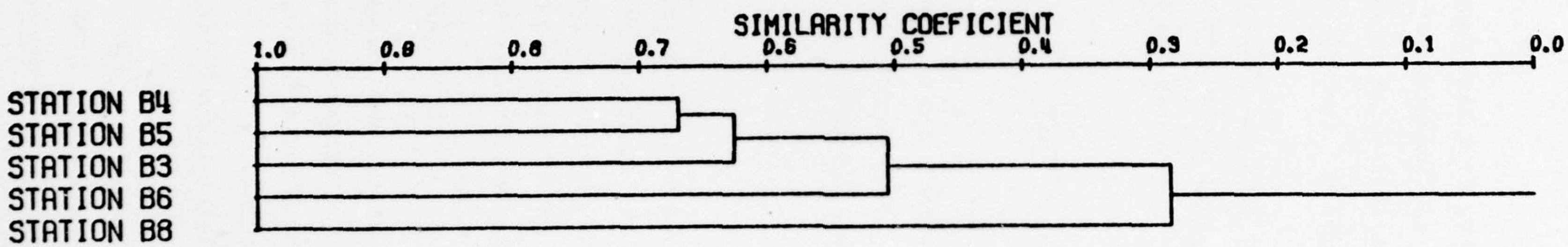
Figure 107.

IAAP BENTHOS-STATION COMPARISON OF NAT. SUB. SURBER-COMB. REP. (OCT 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



At station B8, four taxa comprised 76 percent of the population, with Hydropsyche sp. increasing greatly from 16 percent to 45 percent. Other taxa present in ranking order were Baetis intercalaris (11 percent), Cheumatopsyche sp. (10 percent) and Microtendipes sp. (10 percent).

To summarize Appendix XIX, station B3 had 15 total taxa, stations B4 and B5 both had 11 taxa and station B6 had 18 taxa. Twenty-eight taxa were found at station B8, which is the recovery zone for Brush Creek.

Discussion of Results

Species Occurrence on Artificial Substrates (October 1975) -

Mean benthic macroinvertebrate species diversity increase with distance downstream. This trend is similar to that observed during the May-June survey however the increase was not as great.

Species diversity did not parallel any specific chemical trend. An important shift in diversity occurred between station B7 and station B8 where a sharp decrease in diversity was observed. Cause of this decrease between the two stations is uncertain. This decrease may have resulted from the natural characteristics of the creek or some other unknown inhibitory factor.

Species occurrence and dominance was similar between the stations of Brush Creek. Stations B2 and B3 were dominated by Polpomyia tibialis which was a facultative species[20]. The remaining stations had taxons that were intolerent of organic pollution[36], indicating that the industrial effluents were not greatly affecting the benthic communities.

The proximal stations on Brush Creek were similar above 55 percent except for station pair B7-B8. This indicates that the industrial waste effluents are not drastically changing the species complex between

stations. The dissimilarity between stations B7 and B8 also verifies the sharp decrease in diversity mentioned previously, in that some factor, i.e., natural characteristics of the stream, is causing a change between the two stations.

The observations seen on the artificial substrates indicates that there is very little effect on the benthic macroinvertebrate community from the industrial waste effluents. However, it is uncertain why station B8, the recovery zone, resulted in low diversity and dissimilarity to its adjacent station. The only conclusion to be made of this occurrence is that some inhibitory factor(s) is affecting the macroinvertebrates at this station.

Spring Creek species diversity increased between stations S1 and S2. The low diversity at station S1 was possibly caused by siltation of the stream bed due to construction work upstream. Taxa that occurred at both stations were facultative to intolerent of organic pollution[36].

Species Occurrence on Natural Substrates (October 1975) -

Ponar samples - Species diversity and species occurrence of benthic macroinvertebrates from ponar samples are dependent upon the chemistry of the sediments because they are in direct contact with the soft substrate of the creek. Sediments of this type are more susceptible to sorption of various materials. Mean species diversity was somewhat similar to that observed in May-June ponar samples.

Two important diversity trends occurred within Brush Creek. The first was a sharp decrease in diversity occurred between station B2 and station B4. From station B4, a sharp increase occurred to station B6. This trend corresponds to the sediment TNT levels found in the sediments. Sediment TNT levels were greatest at station B4 (110.6 mg/kg) thus resulting in a very low diversity.

The second important trend in diversity was the decrease that occurred between stations B6 and B8. Low diversity at station B7 is probably caused by the domestic waste treatment plant upstream, however, it is uncertain why station B8 exhibits a low diversity. This is very similar to that observed on the artificial substrates in October and again indications are that some inhibitory factor is adversely effecting the macroinvertebrate population at this station.

Taxa that were abundant at the stations of Brush Creek were primarily intolerent of organic pollution[36]. Lesser important taxa that comprised the station communities were facultative[36] and of the family Chironomidae.

Station similarities were high except between B6 - B7 and B7 - B8. This is the area where diversity decreased greatly and did not correspond to any chemical trend specifically. Again, indications suggest that an inhibitory factor is causing these two stations to be different.

Mean species diversity increased between stations S1 and S2. Construction work upstream had increased greatly since May-June and the sediments at station S1 were heavily silt-covered probably causing the low diversity. The dominant taxa at station S1 comprised a larger percent of the community than what was observed at station S2.

Surber square foot samplers - Mean species diversity from the surber samples shifted significantly between stations. This was shown by the analysis of variance test where F (.95) for the samples was 5.63 and hypothetical F (.95) was 5.62. The greatest shift in diversity was a decrease at station B4 which corresponds to the high aqueous and sediment TNT levels found. However diversity was still fairly high.

Taxa that occurred at the stations were primarily intolerent of organic pollution[36]. Proximal stations were also similar above the 50 percent level. It can be concluded that the riffle area with its harder substrate was least effected by the industrial waste effluents.

Observed trends during the October survey period indicated that the benthic macroinvertebrate communities were most effected by the industrial effluents, when in contact with the soft sediments (ponar samples). The artificial substrates (second closest to the soft sediments) showed a small effect while the riffle areas (surber samples) showed no change. However it was indicated through both artificial and ponar samples that some inhibitory factor was creating a change in the benthic community at stations B7 and B8. This was the same trend as observed during the Spring. The conclusions which can be drawn from the two surveys are:

1) Benthic macroinvertebrate species and species diversity were most effected by the industrial waste effluents when in direct contract with the soft sediments and least effected when associated with harder sediments.
2) Species diversity of the benthic macroinvertebrates indicated some inhibitory factor was present at stations B7 and B8. This cannot be explained due to the absence of toxicological data with respect to these compounds on such organisms. This was also observed in 1974[1].

SECTION VIII
REFERENCES

1. R.L. Weitzel, P.B. Simon, D.E. Jerger and J.E. Schenk. Aquatic Field Survey of Iowa Army Ammunition Plant. U.S. Army Medical Research and Development Command, Washington, D.C. 20314. Contract NO. DAMD 17-74-C-4124. August 1975.

2. USA EHA-ES. Water Quality Engineering Survey No. 24-003-72, IAAP, Burlington, Iowa. 13-17 September, 1971.

3. USA EHA-EW. Water Quality Biological Survey Study No. 24-009-73, IAAP, Burlington, Iowa. 10-19 July 1972.

4. Water Pollution Report. Water Laboratory Materials Testing Laboratory, Mason & Hanger - Silas Mason Co., Inc., IAAP, Burlington, Iowa. Reports No. 1-13, 15 January 1970 - 15 June 1974.

5. Hutchinson, G. Evelyn. A Treatise on Limnology. Volume III. Limnological Botany. New York, John Wiley and Sons, Inc. 1975. 660 p.

6. Mason, William T., Jr., Cornelius I. Weber, Philip A. Lewis, and Elmo C. Julian. Factors affecting the performance of basket and multiplate macroinvertebrate samplers. Freshwat. Biol. 3:409-436. 1973.

7. Mason, William T., Jr., and Paul P. Yevich. The use of phloxine B and rose bengal stains to facilitate sorting benthic samples. Trans. Amer. Microsc. Soc., 86(2):221-223. 1967.

8. Hester, F.E. and J.S. Dendy. A multiplate -plate sampler for aquatic macroinvertebrates. Trans. Am. Fish. Soc., 91:420-421. 1962.

9. Won, William D., Robert J. Heckly, Donald J. Glover and John G. Hoffsommer. Metabolic Disposition of 2,4,6-Trinitrotoluene. Applied Microbiology, 27(3):513-516, 1974.

10. Methods for Chemical Analysis of Water and Wastes. Cincinnati, Environmental Protection Agency, 1974. 298 p.

11. APHA. Standard Methods for the Examination of Water and Wastewater, Thirteenth Edition. New York, American Public Health Association. 1971. 874 p.

12. Analytical Methods for Atomic Absorption Spectroscopy Using the HGA Graphite Furnace. Norwalk, Perkin-Elmer Corp., 1973.

13. Hatch, W.R. and W.L. Ott. Determination of Sub-Microgram Quantities of Mercury by Atomic Absorption Spectrophotometry. Analytical Chemistry. 40(14):2085-2087, December, 1968.

14. Burlinson, N.E., L.A. Kaplan, and C.E. Adams. Photochemistry of TNT: Investigation of the "Pink Water" Problem. Naval Ordnance Laboratory, Silver Spring, MD., Report Number NOLTR 73-172, 1973. 14p.

15. Kaplan, L., U.S. Naval Ordnance Laboratory, Silver Springs, MD., personal communication, 1975.

16. Chemistry Laboratory Manual - Bottom Sediments. Environmental Protection Agency, Great Lakes Region Committee on Analytical Methods, 1969. 101p.

17. Giron, H.C. Comparison Between Dry Ashing and Wet Digestion in the Preparation of Plant Material for Atomic Absorption Analysis. Atomic Absorption Newsletter. 12(1): 28-29, January 1973.

18. Bonchard, A. Determination of Mercury after Room Temperature Digestion by Flameless Atomic Absorption. Atomic Absorption Newsletter. 12(5):115-117, September, 1973.

19. Sitzmann, M.E. Chemical Reduction of 2,4,6-Trinitrotoluene - Initial Products. J. of Chemical and Engineering Data. 19(2):179-181, April 1974.

20. Enzinger, R.M. Special Study of the Effect of Alpha TNT on Microbiological Systems and the Determination of the Biodegradability of Alpha TNT. U.S. Army Environmental Hygiene Agency, Edgewood Arsenal, MD, 1970.

21. McCormick, N.G. Microbial Degradation of Munitions Wastes, Microbial Solutions to Waste Problems Symposium, A.S.M. Meeting, Chicago, 1974.

22. Nay, Marshall W., Clifford W. Randall and Paul H. King. Biological Treatability of Trinitrotoluene Manufacturing Wastewaters. Journal WPCF, 46(3):485-497, 1974.

23. Wilhm, Jerry L. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Pollution Control Federation. 39:1673-1683. 1967.

24. Wilhm, Jerry L. and Troy C. Dorris. Biological parameters for water quality criteria. Bioscience. 18:477-490. 1968.

25. Cairns, John Jr. and Kenneth L. Dickson. A simple method for the biological assessment of the effects of waste discharge on aquatic bottom-dwelling organisms. Journal Water Pollution Control Federation. 43:755-772. 1971.

26. Cairns, John Jr., Guy R. Lanza, and Bruce C. Parker. Pollution related to structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proceedings of the Academy of Natural Sciences of Philadelphia, 124:79-127. 1972.

27. Diaz, R., M. Bender, D. Boesch, and R. Jordan. Water quality models and aquatic ecosystems status, problems and prospectives. In: Models for Environmental Pollution Control, R.A. Deininger, ed. Ann Arbor: Ann Arbor Science Publishers. pp. 137-153. 1973.

28. Patrick, Ruth. Use of algae, especially diatoms, in the assessment of water quality. In: Biological Methods for the Assessment of Water Quality, ASTM STP 528. American Society for Testing and Materials. pp. 76-95. 1973.

29. Hurlbert, Stuart H. The nonconcept of species diversity: A critique and alternative parameters. Ecology, 52(4):577-586. 1971.

30. Patrick, Ruth. Diatoms as bioassay organisms. In: Bioassay Techniques and Environmental Chemistry. G.E. Glass, ed. Ann Arbor:Ann Arbor Science Publishers, Inc. pp139-151. 1973.

31. Hohn, Matthew H. and Joan Hellerman. The taxonomy and structure of diatom populations from three Eastern North American Rivers using three sampling methods. Trans. Amer. Micros. Soc., 86(3):250-329. 1963.

32. Patrick, Ruth and Charles W. Reimer. The diatoms of the United States exclusive of Alaska and Hawaii. Monographs of the Academy of Natural Sciences of Philadelphia. Number 13. Philadelphia:The Livingston Publishing Company. 1966. 688p.

33. Odum, E.P. Fundamentals of Ecology. 3rd Edition. Philadelphia: W.B. Saunders Company. 1971 574p.

34. Pinkham, Carlos F.A. and J. Gareth Pearson. A new coefficient of similarity between samples and its applications to pollution surveys. Ecological Research Office, Biomedical Laboratory, Edgewood Arsenal. Aberdeen Proving Ground, Maryland. 20p.

35. Pinkham, Carlos F. A. and J. Gareth Pearson. Applications of a new coefficient of similarity to pollution surveys. J. Water Pollution Control Federation. 48:717-723. 1976.

36. Weber, Cornelius I. Biological field and laboratory methods for measuring the quality of surface waters and effluents. Office of Research and Development, U.S. Environmental Protection Agency. Cincinnati, Ohio. EPA-670/4-73-001. 1973.

37. Vollenweider, R.A. A manual on the methods of measuring primary production in aquatic environments. IBP Handbook No. 12. Oxford and Edinburgh, Blackwell Scientific Publication. 1969. 213p.

38. Slack, K.V., R.C. Averett, P.E. Greeson, and R.G. Lipscomb. Methods for collection and analysis of aquatic biological and microbiological samples: Techniques of Water Resources Investigations of the United States Geological Survey. Chapter 4A. United States Department of the Interior. 1973. 165p.

39. Weber, cornelius I. Recent developments in the measurement of the response of plankton and periphyton to changes in their environment. In: Bioassay Techniques and Environmental Chemistry, Gary E. Glass, ed. Ann Arbor: Ann Arbor Science Publishers, Inc. 1973. pp. 119-138.

40. Christian, R. R., K. Bancroft, and W. J. Wiebe. Distribution of microbial adenosine triphosphate in salt marsh sediments at Sapelo Island, Georgia. Soil Science, 119(1):89-97. 1975.

41. Cheer, Sue, John H. Gentile, and C. S. Hegre. Improved methods for ATP analysis. Analytical Biochemistry, 60:102-114. 1974.

42. Holm-Hansen, Osmund. ATP levels in algal cells as influenced by environmental conditions. Plant Cell Physiology, 11:689-700. 1970.

43. Holm-Hansen, Osmund. Determination of total microbial biomss by measurement of adenosine triphosphate. In: Estuarine Microbial Ecology, L. H. Stevenson and R. R. Colwell, eds. University of South Carolina. 1973. pp. 73-89.

44. Lowe, Rex. Environmental requirements and pollution tolerance of freshwater diatoms.

45. Personal Correspondance. Gary B. Collins. Biological Methods Branch, U. S. Environmental Protection Agency. Cincinnati, OH.

DISTRIBUTION LIST

4 copies	Commander, USAMRDC ATTN: HQDA (SGRD-RP) Wash, DC 20314
12 copies	Defense Documentation Center (DDC) ATTN: DDC-TCA Cameron Station Alexandria, Virginia 22314
1 copy	Superintendent Academy of Health Sciences, US Army ATTN: AHS-COM Fort Sam Houston, Texas 78234
1 copy	Dean School of Medicine Uniformed Services University of the Health Sciences Office of the Secretary of Defense 6917 Arlington Road Bethesda, MD 20014
25 copies (4 with appendices)	Environmental Protection Department ATTN: SGRD-UBG US Army Medical Bioengineering Research and Development Laboratory Fort Detrick, Frederick, MD 21701